THE JOURNAL OF ENGINEERING EDUCATION

Published by THE SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION

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VOL. XXVI., NO. 9

MAY, 1936

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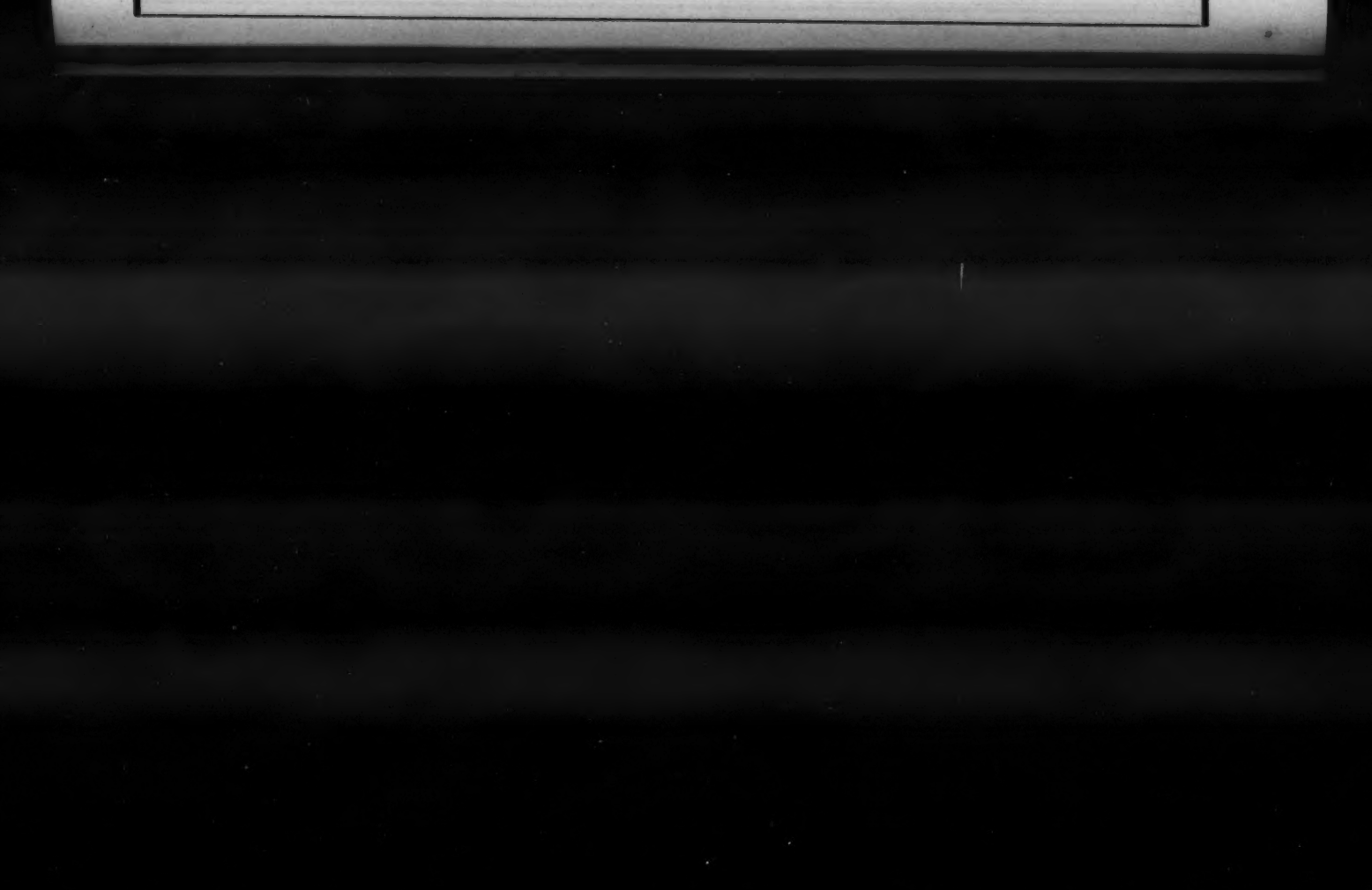

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THE JOURNAL OF ENGINEERING EDUCATION

Published by the Society for the Promotion of Engineering Education

Published under the Supervision of the Publication Committee.
D. S. Anderson, C. C Williams, F. L. Bishop, Editor, University of Pittsburgh.
Published at Prince and Lemon Sts., Lancaster, Pa.

Entered as second-class matter at the Post Office at Lancaster, Pa., under the Act of March 3, 1870.

New Series
Vol. XXVI, No. 9. MAY, 1936 Subscription Price, $3.00 per year. Single Copies, 50 cents

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COME TO MADISON!

By D. S. ANDERSON, President

When the writer was elected to the presidency of this Society, no small part of the pleasure experienced by him in the reception of this entirely unexpected honor was the announcement that the annual meeting was to be with the University of Wisconsin at Madison. This feeling of pleasure arose from several sources: pleasant memories of a former visit to Madison following the annual meeting in Chicago in 1933, the opportunity afforded us of inspecting the plant and equipment of one of the great engineering schools of the country, and above all the occasion it furnishes for honoring one of the outstanding pioneers of engineering education in this country and one of the veteran members of the Society for the Promotion of Engineering Education.

Professor Van Hagan's article with the attractive pictures of Madison in the March issue of the JOURNAL, coupled with the fact that here in the far South spring has already turned into summer, brings one a feeling of *wanderlust* to the extent that one would like to get into his car and start for Wisconsin at once.

Each new president hopes that the annual meeting in his administration will break the record for attendance, or at least that it will not fall too far below the mark in this respect, and I am no exception to this. With all the attractions offered us by our host institution and with the excellent program being arranged by Secretary Bishop and the Program Committee, it would seem that every member would make every effort to be present. It is unfortunate, but inevitable, that there should be some conflicts in dates, notably with the A. I. E. E. on the Pacific coast and with the A. S. M. E. in Texas. The dates of our meeting at the University of Wisconsin were controlled by the closing of their regular session and the opening of their summer session, and there was no other choice.

The point has been made a number of times that we should make special effort to get the younger men to these meetings. A number of institutions do this and they extend some sort of financial assistance toward this end. I know of an institution which pays a substantial portion of the travelling and other expenses of the younger members of its faculty who prepare and present papers at the annual meetings of national societies. In these days of travel by automobile, with tourist camps and inexpensive accommodations

in college dormitories, a trip to Madison even from a distant point could be made at a very reasonable expense. (See also notice in this issue concerning reduced railroad fares.)

Last June the membership responded generously and loyally to the call and, coming to Atlanta from all parts of the country, gave us a meeting well up to the records for numbers in attendance. It is my earnest hope that all parts of the country will respond again, and at the same time I wish to appeal particularly to the engineering schools of the South to send strong delegations to Madison.

While attention has been called in Professor Van Hagan's article to some of the attractions of Madison, the opportunity alone to visit and to inspect the work of the United States Forest Products Laboratory should have a special appeal to men from this section of the South, where the proper care and effective utilization of the extensive but decreasing tracts of timber concerns one of the country's most important sources of potential wealth.

And don't forget to bring the family! This is a fine opportunity, both as to time and place, for a very enjoyable outing.

REDUCED FARE TO MEETING AT MADISON

The Program Committee expects to have the preliminary program of the 44th annual meeting to be held at the University of Wisconsin, June 23–26, 1936, in the hands of all members not later than May 11. An identification certificate for use in securing reduced railroad fares will be enclosed with each program.

These identification certificates are issued to members of the Society only. They are good for the personal transportation of the member and/or dependent members of his family. If you do not use your certificate please return it to the Secretary for cancelation.

Round-trip tickets will be sold at FARE AND ONE THIRD of the current one-way first-class fares with minimum of $1.00 upon presentation of identification certificates certifying that holder is a member of the Society or a dependent member of family of a member. Tickets will be validated at Madison by agents of the railroads.

Members are urged to use these certificates in purchasing transportation to the meeting. Even though your fare is only $1.00 use the certificate so that those members traveling considerable distances may receive the benefit of the fare and one third. To some this saving may be their only means of attending the meeting.

ENGINEERING AT THE UNIVERSITY OF WISCONSIN

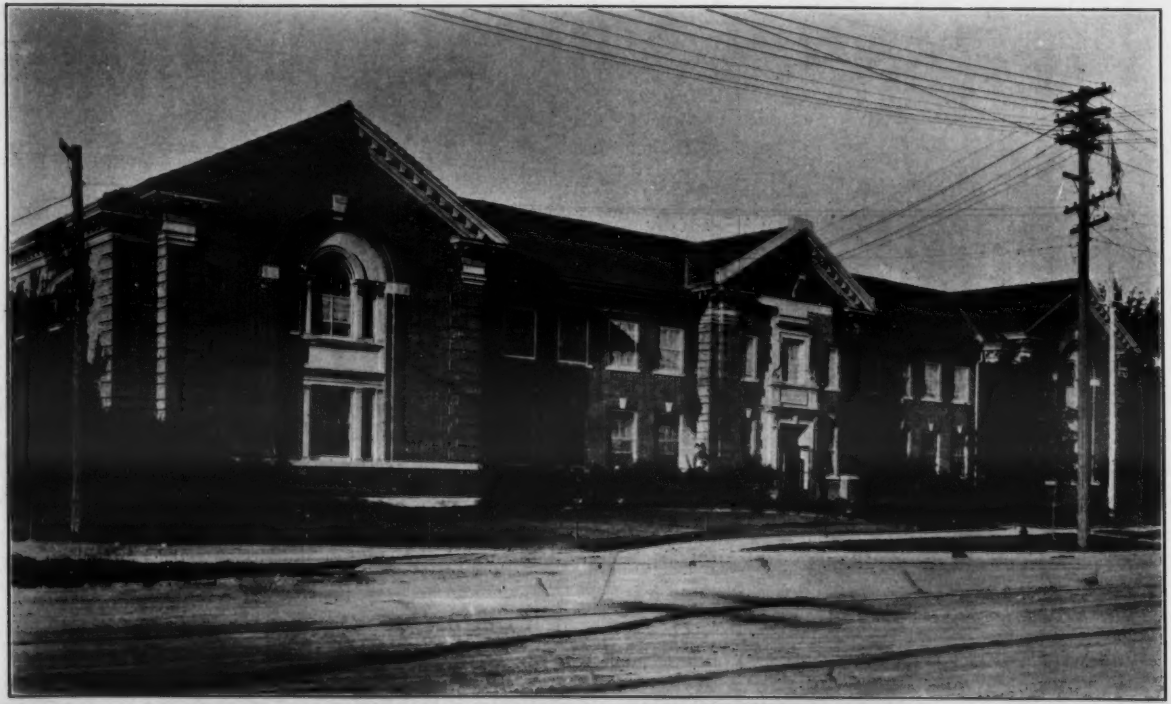
By L. F. VAN HAGAN

Members of the Society for the Promotion of Engineering Education who attend the meeting at the University of Wisconsin in June should be in condition to meet some demands upon their walking ability. The old or main Engineering building is located half way up the hill dominated by Bascom Hall, and to many climbers half way up is sufficient. That is far enough to bring into play leg muscles that do not usually get much exercise and to produce gentle puffing in the corpulent dwellers of the plains. Furthermore, the buildings that constitute the engineering group are separated by a considerable distance. The trek from the Chemical Engineering building to the new Mechanical Engineering building is six tenths of a mile as the crow flies and eight tenths as the student plods his more devious way. Of course, to the drivers of cars distance and climb hold no significance.

The College of Engineering at the University of Wisconsin occupies six buildings: Main Engineering building, Hydraulic Laboratory, Chemical Engineering building, Electrical Laboratory, Mining building, and the Mechanical Engineering building. The first five of the buildings are grouped closely at the eastern end of the campus; the last two are grouped at a distance of half a mile from the first group. It is hoped that this separation, which has serious disadvantages, is only a temporary condition. The plan is to consolidate the college ultimately at the site of the Mechanical Engineering building.

Organization

The organization of the college is compact, with one dean heading the entire engineering faculty. Although the college grants degrees in only five courses, it is organized into twelve departments: mechanics, drawing, electrical engineering, chemical engineering, mining and metallurgy, mechanical engineering, railway engineering, highway engineering and city planning, structural engineering, hydraulic and sanitary engineering, and topographic engineering. In addition there are the shops and the college library. The college also maintains a mechanician's shop. Until the new Mechanical Engineering was built in 1931, the various departments were in close contact. Faculty relationships are very friendly and characterized by a strong *esprit de corps*.



MAIN ENGINEERING BUILDING, UNIVERSITY OF WISCONSIN

An important factor in maintaining close and friendly relationships in the college has been the organization of the women relatives of the faculty into a group known as *Pentagon*. *Pentagon*, which incidentally has no dues, holds regular monthly meetings at the various homes and has been successful in binding the

HYDRAULIC AND SANITARY LABORATORY

MECHANICAL ENGINEERING BUILDING

women closely together. The women are even better acquainted with one another than are the men of the faculty. A spring picnic at Bungalowen, the home of Professor Ray Owen on Lake Monona, has become a traditional feature of the social life of the college. It

MINING AND METALLURGY BUILDING

brings together the faculty with their wives and children, at least once a year, in a meeting that seems to be greatly enjoyed.

SUMMER CAMP

The college maintains a summer survey camp at Devils Lake State Park, thirty-five miles north of Madison in the Baraboo Ridge. The university has a lease on a five-acre tract in the park, which is sufficient for the camp site. The survey work, of course, covers a much larger area. The buildings include an old barn, which

SUMMER SURVEY CAMP AT DEVILS LAKE

has been converted into offices and a drafting room; a combined kitchen, mess hall and commissary; and a number of concrete tent floors. Faculty and students live in tents, which are provided with electric light.

Devils Lake is a beautifully clear body of water, a mile and a quarter long by half a mile wide and surrounded by bluffs that rise five hundred feet above the water. A double-track railroad runs along one side of the lake. The situation and the topography are ideal for the purposes of the camp. Here the sophomore civil engineering students spend six weeks in practice surveys immediately following the spring examinations. The camp will be in session during the meetings of the society in June, and visitors will be more than welcome. The region has great interest from a geological point of view and is well worth a visit for those who appreciate that aspect.

History of Engineering at Wisconsin

The story of engineering education at the University of Wisconsin begins with the acceptance by the state of the federal land grant of 1862, an acceptance that obligated the university to furnish instruction in engineering and in military science. Col. W. R. Pease was detailed to the university in 1868 to teach military tactics and was appointed by the Regents as professor of engineering. He was the first teacher of engineering at Wisconsin, but he stayed only one year, and his successor, Col. William J. L. Nicodemus, who was appointed professor of military science and civil engineering in 1870, has been called "the father of technical instruction at Wisconsin." Colonel Nicodemus served until his death in 1879, and the first engineering students were graduated during his regime.

Colonel Nicodemus had as a colleague Professor Roland D. Irving, who, in 1870, was appointed professor of geology, mining and metallurgy. Courses in civil, mechanical, and mining and metallurgical engineering constituted the curriculum until the first electrical students entered in 1889.

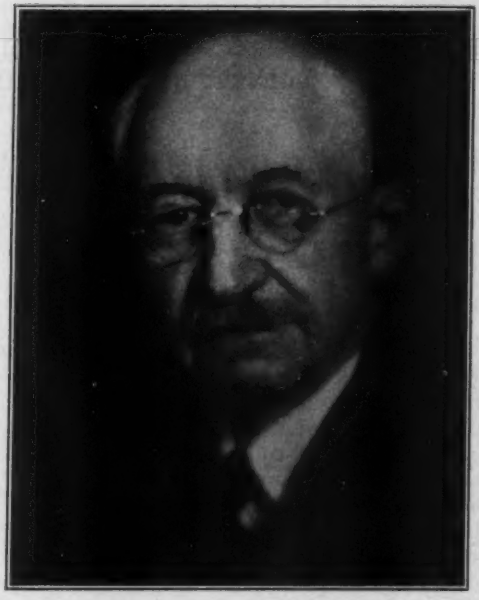
The first classes in engineering were held in University Hall, now Bascom Hall. When Science Hall was ready for occupancy in 1877, the engineering classes moved into that building. This was an important event, for now there was space for shops. Charles I. King was appointed superintendent of shops in the same year and immediately secured a small steam engine and a few machine tools. "Up to this time," writes Professor Storm Bull, "there had been no engineering laboratory, and the machine shop was here,

as nearly everywhere, the first indication of the transformation of engineering education from that of simple book work to a combination of this with practical illustrations of the work gone over in the class room."

In 1884, Science Hall burned with the loss of all it contained, and the engineering teachers and students had to be crowded into hastily prepared quarters on the fourth floor of North Hall. Although the fire caused much loss and was followed by a period of gloom, it proved to be a stroke of fortune for the engineers. The Regents were forced to go to the legislature with a request for funds for rebuilding and the legislature was in a compliant mood. Four new buildings were authorized: a new Science Hall, a chemical laboratory, machine shops, and a power heating plant.

The year 1887 was an important year for engineering at Wisconsin. The new buildings were occupied in that year. Considerable equipment for engineering courses was bought with the insurance money, "so that with the enlarged and better quarters and equipment the outlook for technical education at the University of Wisconsin certainly was much brighter than ever before." Of still greater importance was the appointment of Professor T. C. Chamberlin as president of the university. He took a deep interest in technical education, which up to his time had been regarded as a dirty-faced step-child of the university, and the Board of Regents willingly supported him in his efforts to create a College of Engineering. In 1889 the legislature passed an amendment to the fundamental law establishing the university, whereby the College of Mechanics and Engineering was established, and provided that one per cent of all license fees paid by the railroads into the state treasury should be devoted to the college. In 1890 Congress passed the Morrill grant of direct financial aid to the land-grant colleges, and the regents voted two fifths of this grant to the college. The college now had an income of about $24,000. A course of electrical engineering was introduced in 1889 and three new professorships were established in 1891. From 1889 onward the number of engineering students increased steadily under the direction of the engineering faculty organized as a Board of Engineers.

The next forward step came in 1899 when Professor J. B. Johnson was appointed first dean of the college. He took up his new duties in February of that year with the great enthusiasm and energy that characterized all of his activities; and it was largely through his efforts that an appropriation was secured that same year for an engineering building. It was ready for occupancy in the fall of 1900, and the College of Engineering now had a real home on the campus. The tragic death of Dean Johnson in 1902 was a stunning blow to the college.



DEAN F. E. TURNEAURE

Professor F. E. Turneaure was appointed acting dean of the college in June, 1902, and on January 19, 1904, was made dean. This thirty-two years of service has been a period of activity and accomplishment. The course in mining and metallurgy, which had been discontinued in 1893, was reëstablished, and a new course in chemical engineering was provided. He induced Daniel W. Mead to head the department of hydraulic and sanitary engineering in 1904 and secured the construction of a hydraulic laboratory in 1906. The engineering building was enlarged in 1907 and in 1931 the Mechanical Engineering building was completed and occupied. The faculty has increased from 29 in 1902 to 81 in 1935. Student enrollment increased from 585 in 1902 to 1,064 in 1935.

HOW GOOD IS MY COLLEGE OF ENGINEERING?*

By D. S. ANDERSON, President of the S. P. E. E.

When I started to choose a title for this brief address I first wrote it "How Good is Your College of Engineering?" To make it sound less impertinent and more pertinent I have changed the title to "How Good is My College of Engineering?", thus putting the question squarely up to myself as well as to you. All of us recognize the value and the importance of pausing at intervals in the course of regular routine and taking stock, as it were, of our activities. This is of particular importance at the present time when the Society for the Promotion of Engineering Education is sponsoring for the first time in its existence a plan for the certification of schools of engineering. With this thought in mind some weeks ago I wrote an editorial for the March issue of THE JOURNAL OF ENGINEERING EDUCATION with the title "Imponderables"; some of you may have read it. Whether you did or did not I shall use certain parts of it in what I wish to say to you on this occasion.

For forty years of its existence the Society refrained from setting itself up as an accrediting or standardizing agency, in which attitude it differed quite distinctly from the associations of the professional schools of medicine and law. The necessity for such standardization for schools of medicine and law lies in the fact that the practice of each of these professions is regulated by statute and the privilege of entrance into the profession must be secured through legally constituted channels.

The word "engineer" has probably been, with the exception of "professor," the most abused title of any of the professions. The range of functions and abilities as implied by the title extended from the man who knew enough to shovel coal into a stationary boiler to the man who could envisage and design a San Francisco bridge. Real professional engineers for a number of years past have been awakening to the seriousness of this situation and are taking steps to change it. The keynote to any such consummation lies in the proper regulations for admission to the profession.

One of the most significant phases of our attempts to protect and to dignify the title of "engineer" is the rapidly increasing adoption of registration laws throughout the country. As stated by

* Presented at the meeting of the Southeast Section, S. P. E. E., University of Alabama, April 8, 9, 1936.

Dean Daggett in an editorial in the October 1935 issue of THE JOURNAL OF ENGINEERING EDUCATION the principle of engineering registration is now an accomplished fact in all but thirteen of the States. This is a matter of outstanding importance to the schools of engineering for the simple reason that the engineer of the present and of the future is to be a college trained product. But at the same time proper recognition must be given to the fact that the profession of engineering is to be one of very much wider scope than that of either medicine or law, particularly when one heeds the insistent demand that the engineer must be prepared to assume his fullest responsibilities in relation to the social and economic problems of our modern civilization, some of the most prominent features of which are regarded by so many as largely a result of the activities and inventions of the engineer and the scientist.

An event of the most far-reaching influence upon the professional status of the engineer was the organization in 1932 of the Engineers' Council for Professional Development, the organization being made up of representatives of the five national engineering societies, the National Council of State Boards of Engineering Examiners and our own Society for the Promotion of Engineering Education.

In its charter the purpose of the organization is stated as follows:

"The general objective of E. C. P. D. is the enhancement of the professional status of the engineer. To this end it aims to coördinate and promote efforts and aspirations directed toward higher professional standards of education and practise, greater solidarity of the profession, and greater effectiveness in dealing with technical, social, and economic problems.

"An immediate objective, now apparently practicable of attainment, is the development of a system whereby the progress of the young engineer toward professional standing can be recognized by the public, by the profession, and by the man himself, through the development of technical and other qualifications which will enable him to meet minimum professional standards."

For the attainment of these objectives four standing committees have been set up, whose functions may be briefly stated as follows:— The Committee on Student Selection and Guidance shall report to E. C. P. D. means for educational and vocational opportunities in order that those seeking entrance to the profession may have the high quality, aptitude, and capacity required of its members. The Committee on Engineering Schools shall deal with the problem of coöperation between the engineering profession and the engineering schools. As an immediate step this committee is to report to the

Council criteria for colleges of engineering which will insure to their graduates a sound educational foundation for the practice of engineering. The Committee on Professional Training shall devise plans for the further personal and professional development of young engineering graduates, and also of those without formal scholastic training. The Committee on Professional Recognition is to plan methods whereby those engineers who have met suitable standards may receive corresponding professional recognition.

All of these committees are functioning actively, but it is the Committee on Engineering Schools and its immediate objective in which we are specially interested at the present time, for the reason that this committee through the E. C. P. D. is to undertake the important task of accrediting our engineering schools.

The accrediting procedure involves the division of the country into seven districts in each of which there shall be a delegatory committee with representatives from each of the constituent societies whose duty it shall be to secure the necessary data and to make the inspections upon which the accrediting is to be based.

All of the engineering schools which are members of the Southeastern Section, with the exception of Louisiana, are in Region No. 4, the representative from the S. P. E. E. being Dean B. M. Brigman of the University of Louisville. Louisiana has been placed in Region No. 5, Dean G. C. Shaad of the University of Kansas being the representative for that district. In the organization of these delegatory committees college people will be depended upon principally, but at least one member of each committee shall be an engineer not on the staff of any engineering school.

When the regional committee is ready to proceed with the accrediting, letters of information are sent to each of the degree granting schools. The inspection is made only upon the request of the school, itself. A fee is charged on the basis of $100 for the first curriculum submitted for accrediting; $50 for each additional curriculum, with a maximum of $400 for any one school.

It is of interest to note the salient features of the basis for the accrediting of engineering schools as adopted by the E. C. P. D.

Accrediting is to apply only to those curricula, both graduate and undergraduate, which lead to degrees.

Curricula in each institution are to be accredited individually. For this purpose, the E. C. P. D. will recognize the six major curricula: chemical, civil, electrical, mechanical, metallurgical, and mining engineering. These are represented in its own organization through the national member societies. Other curricula may be accredited where warranted by the educational and industrial conditions pertaining to them.

Curricula are to be accredited on the basis of both qualitative and quantitative criteria. Qualitative criteria are to be evaluated through visits of inspection by a committee or committees of qualified individuals representing the E. C. P. D. Quantitative data are to be secured from catalogs and other publications, and from questionnaires.

Quantitative criteria are to include the following:

Auspices, control, and organization of the institution and of the engineering division.
Curricula offered and degrees conferred.
Age of the institution and of the individual curricula.
Basis of, and requirements for, admission of students.
Number of students in the engineering college as a whole and in the individual curricula, respectively.
Graduation requirements.
Teaching staff and teaching loads.
Physical facilities. The educational plant devoted to engineering education.
Finances: Investments, expenditures, sources of income.

Qualitative criteria are to include:

Qualifications, experience, intellectual interests, attainments, and professional productivity of members of the faculty.
Standards and quality of instruction, both in the actual engineering departments and in the scientific and other coöperating departments in which engineering students receive instruction.
Scholastic work of students.
Records of graduates both in graduate study and in practice.
Attitude and policy of administration toward its engineering division and toward teaching, research, and scholarly production.

This basis for the accrediting of our schools embodies most excellent principles and gives promise of avoiding some of the errors which have been found to exist in several of the more prominent standardizing or accrediting agencies of this country.

As may be readily seen, the most valuable features of the E. C. P. D. system are the avoidance of absolute minimum standards of educational processes, the accrediting on the basis of individual curricula rather than on the basis of the school as a whole, and the emphasis on qualitative as compared with quantitative criteria.

It is this last feature of the emphasis on qualitative criteria which suggested the title of the brief editorial, to which reference has been made. Quantitative data are easy to secure; the same thing may be said of certain of the qualitative criteria, which it is

proposed to evaluate through visits of inspection by committees of qualified individuals. The "imponderables" in an institution, as the name implies, are difficult of evaluation, because of their subjective rather than their objective character. There are certain large and well-established engineering schools with extensive material equipment and faculties of distinguished scientific and engineering men, the accrediting of which would be almost a matter of form. On the other hand there are other schools with far less equipment, with less distinguished men on their faculties and with reputations extending not far beyond the sections they serve, which are doing excellent work and turning out a product in the form of small graduating classes of men who have demonstrated their ability to measure up to the best standards of the profession. These schools have in them a good measure of what have been termed the "imponderables." And when they are inspected by "committees of qualified individuals" it is going to be the solemn duty of these individuals to search out carefully and sympathetically these imponderables. Paradoxical as it may sound, there are imponderables which may be discovered and even weighed.

When Dean Field requested me to speak at this meeting he made this very significant statement—"I feel that it is very essential that we take sufficient time to determine in our own minds something of the future for engineering education in the southeast and to determine if possible whether or not it is necessary to change immediately our present courses in order to meet the requirements of the accrediting group which will be inspecting our Engineering Colleges within the next few years."

This brings us around now to the question which I have used as the title for this paper—"How Good is My College of Engineering?" I personally believe there is no reason for over-anxiety on the part of any well organized school of engineering, such as the ones which comprise the membership of this Southeast Section, with reference to any unfavorable attitude on the part of the accrediting committees which may come to inspect us. The E. C. P. D. expressly states that it is not a part of its accrediting program to set up absolute minimum standards of educational processes. Take for instance the mechanical engineering curriculum of one of our colleges; as I look at the matter, they will wish to secure enough information, both quantitative and qualitative, upon the basis of which they may decide whether or not the school in question is giving an adequate degree of teaching to fit the graduate to take his place as a young engineer just entering the profession. It is perfectly possible that one school may do this with resources and equipment, and in a way, quite different from those of another school.

I think if I were a member of one of these accrediting committees I should like to ask such questions as these:

What is the basic attitude and spirit of the general administrative control? Is the school free from the sort of administrative functioning, political or otherwise, which insists upon meddling with details instead of leaving these to the members of the staff who are qualified by special training and experience to assume the responsibility?

Is the President thoroughly sympathetic and coöperative with the Dean in his efforts for the welfare and progress of the school?

Within the available financial resources of the school is the Dean given a reasonably free hand in setting up his budget of expenditures?

Is it the policy of the Dean to place the responsibility for the efficient operation of each department squarely up to the staff of the same?

In the selection of members of the faculty of professorial rank, in the consideration of qualifications, where do we place the major emphasis; upon ability and experience as a teacher or upon reputation for research and professional productivity?

Is due consideration given to the personality and character of the prospective appointee? In this connection is it customary to insist upon a personal interview before the appointment is finally made?

Does the school recognize frankly its limitations and accordingly turn its attention to the development to the highest possible standards of its fundamental curricula rather than to spreading its resources over a wide field of highly specialized courses, whose value for advertising purposes may considerably outweigh their training and educational value?

For the student body, with reference both to admission and to subsequent retention, is the emphasis upon quality or upon quantity?

Are the scholastic requirements of our schools of engineering, both as to content and scheduled hours of the different courses, so exacting as to leave the student very little, if any, time for participation in worth-while student activities?

Do we encourage our best students to extend their training through graduate study and research?

Obviously, there are many other questions which can be, and will be asked concerning your school and my school; what I am trying to emphasize is that high standards and effective training depend so much more upon the quality, the ideals and the spirit of your faculty and student body than they do upon mere size and extent of your material resources. It is not in my thought, at all,

to underestimate the essential value of material resources; we must have them, and this is particularly true in relation to our schools of engineering. But in the true and significant evaluation of the effectiveness of our schools, these other questions noted above should receive the greater emphasis.

May I illustrate this point by a bit of experience which came to my attention a number of years ago when attending a meeting of a national scientific society at a large university which had a comparatively small school of engineering. This school had a small but able faculty, but much of its equipment was not of the latest model. A small group of visitors were making a somewhat casual inspection of a certain laboratory when one of them in language more forceful than tactful characterized its equipment as being fit only for the junk heap. And yet there had gone out from that same laboratory each year small groups of graduates, a number of whom stand at the very top of the profession in the respective lines of activity for which they had been trained. Much of the engineering instruction received by these men came from a devoted professor of physics, who had the ability and the imagination to see the practical applications of the fundamental principles which he taught with so much zeal and inspiration.

You, no doubt, know something of the new basis for the accrediting of higher institutions which, after four years of careful study, is now in process of adoption by the North Central Association of Colleges and Secondary Schools. The fundamental idea of this new plan involves the expression of the criteria for accrediting in the form of statements of policy rather than statistical and quantitative standards. One section of this statement of policy appeals to me particularly as illustrating what I have been trying to express in this paper, and I believe it has a rather specific application to our situation in these Southeastern states. It is as follows:

"In its accrediting procedures the Association intends, within the general pattern of higher education, to observe such principles as will preserve whatever desirable individual qualities member institutions may have. While it is necessary to emphasize certain characteristics that are recognized as basic, such as the competence of the faculty, the representative character of the curriculum, effective administration, standards of student accomplishment, and financial adequacy, it is regarded as of prime importance also to protect such individual variations as appear to be educationally sound. Even in these basic matters it is clear that considerable divergence from average or optimum conditions may occur without perceptibly detracting from the essential educational worth of an institution. Uniformity in every detail of institutional policies and practices is believed to be not only unnecessary, but undesirable. Well con-

ceived experiments aimed to improve educational processes are considered essential to the growth of higher institutions and will be encouraged."

In the twenty-ninth annual report of The Carnegie Foundation for the Advancement of Teaching, President Jessup presents something of this same point of view in a paper entitled, "Facing Actualities in American Higher Education." The fundamental thesis of this paper is a plea to our colleges to turn their thoughts less to conformity with mechanical and quantitative standards and more towards the consideration of the opportunities for each college to work out its own individual destiny. When this is done in the proper spirit it should be possible in the words of Dr. Jessup "for the institution to define its purpose, differentiate its function, teach what it has to offer, teach what it can pay for, and once again to recognize the face that the heart of the problem is the need of the student on the one hand and the resources of the institution on the other."

This, I believe, will be the spirit in which the accrediting of our colleges of engineering will be administered by the E. C. P. D.

If then we can answer frankly and conscientiously in the affirmative the questions that have been asked further back in this paper, is it not within reason for us to feel assured that the schools of engineering, which are members of this Southeastern section, will measure up successfully to the accrediting policies of the Engineers' Council for Professional Development?

And as one who has spent over forty years in the field of engineering education, I should like to feel that here in the South, as well as all over this country, our schools of engineering will be turning their attention more and more to the broad problems of adjusting our curricula and of directing the activities and the social and community life of the student in the few short years he is with us, so that we may, in the words of President Wriston, "make the appeal which matches his dearest and most secret ambition—to be a significant person, physically, intellectually, emotionally, spiritually."

RE-EVALUATION OF ENGINEERING DRAWING *

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During the past five or six years the question of the place of the subjects of Engineering Drawing and Descriptive Geometry in the engineering curriculum has been very much to the fore. Opinions have varied widely as to the importance of the two subjects and serious questions have been raised from time to time as to whether or not one or both subjects might not be entirely eliminated from certain curricula. On the other hand, more carefully measured opinions have been to the effect that the teaching of the subject has in many cases been sadly underdone and that many inherent values, particularly in the developing field of orientation and guidance, have been overlooked. It is because of the growing opinion that these courses need a broader, more effective and more carefully developed program, that the present discussion of the subject is submitted. It is based largely on the studies of the Division of Engineering Drawing and Descriptive Geometry of the S. P. E. E. during the past six years. It attempts to indicate the contribution that Drawing may make to the newer field of orientation and outlines a program by means of which those ends may be reached.

Before entering into the general development of the topic indicated by the title, I feel it important that we differentiate between several terms about which there has grown a considerable confusion in recent years. These terms are "orientation," "personnel work" and "guidance," as applied to educational programs.

Orientation is general and informative. Its material is drawn from engineering practice and related to engineering education. As a teaching program, it is subject to all the implications of such a background. Persons who present it should be bound by obligations and restrictions which apply to any other subject in the curriculum. As we review the matter, it seems obvious that orientation is temporary; it lies in the field of "materials correlation and stock production." An orientation program, as applied to an engineering student, consists, first, in informing him of the nature of the work which engineers do and, if possible, giving him a personal view of the environment in which it may be done, more par-

* Presented at the Atlanta Meeting of the S. P. E. E., June, 1936.

ticularly, those branches of the profession in which a student may later become interested; second, to present for his consideration a list of aptitudes and professional qualifications which are desirable for general engineering work and to emphasize those which are essential for a particular branch of engineering endeavor; third, to foster the development of such aptitudes as may be exhibited by the student and either to develop or eliminate such qualifications and personal attributes as may be indicated in each individual; fourth, to provide a broad fundamental program of training necessary to prepare a student for such fields of work; and fifth, to develop this program in such a way as to make it a drill in the right method of approach to an engineering problem and a practice in those attributes which ordinarily should promote progress in the engineering profession. The entire procedure should be developed so as to promote on the part of each individual a free, rather than a prescribed, selection of type of engineering.

Personnel work is analytical and individual; it is impersonal and specific. Its background is a cumulative mass of material developed during the educational and professional life of an individual and then modified by economic conditions. Personnel work is essentially a business program and subject to all the requirements of a good business program. This implies on the part of the personnel administrator not only a thorough knowledge of the student group and graduate bodies, but a keen appreciation of economic conditions and trends. A wide and harmonious contact with business people is an obvious prerequisite for such work. It involves elements other than the individual. Personnel work, in the wide sense, lies in the field of "successive stock inventory and salesmanship to the best available market."

Guidance is distinctively individual, personal and paternal, so much an interrelation of the whole student and broad programs as represented by a highly specialized curriculum given for definite purposes that it must be handled by experts of broad experience in these essentials. Guidance, therefore, seems to me to lie definitely within the obligation of the administrative head of each particular free-choice group. Some factors in the guidance problem admittedly are best understood on the basis of the work done by the orientation or personnel groups. However, these results are largely evidential and are so frequently the result of the student plus the program that the effects should not be judged by those who present orientation material or develop personnel data. This implies that in guidance the point of view of the administrators must be entirely judicial. To be completely effective it may in the case of over-enthusiastic students be restrictive or, in the case of the laggard student, encouraging and inspirational.

Orientation has the higher preliminary importance, guidance a high interim value, but personnel work has a permanent place, continuing on past graduation into the professional life of the individual. It may even go to the extent of capitalizing the success of the individual for the sake of the prestige of the institution. Guidance is a terminal program ending with graduation. Orientation assumes the obligation not only of interesting the indifferent, but of motivating the mastery of a fundamental program, looking towards definite specialization. Orientation is constant and may be made immediately corrective through coöperation in the guidance work. During the first year, at least, there is one point which is obvious. There must not, in any of the three programs, be any element which by any means whatever permits the development or provides the student with excuses for failure to meet all his obligations to himself, his family, or his school.

As to the relative merit of one way which has been tried, may we quote from the report of the Carnegie Foundation for the Advancement of Teachings on the special advisers system. "In the first place, advisers were appointed or did their work much too late to have any effect on the problem; secondly, they were almost invariably unofficial, usually having merely voluntary and infrequent interviews with their assigned students. And third, they conceived their task in the casual spirit of the earlier "faculty adviser," contenting themselves with the miscellaneous personal and social affairs of the student rather than going after the main point, namely, his mental operations as a college man seeking an education appropriate to his talents and his interests."

Another line of attack has been the development of special courses in engineering problems, given to all students their first year in college. Since problems courses must cover all fields of engineering, the allocation of the work has demanded that a special department be set up, introducing a new element of confusion into the educational situation. This method has been open to the very pronounced criticism that, since the problems must in many cases be considerably modified to accommodate the freshman intelligence, it "muddies" the water for later and more professional treatment of the subjects in the later courses from which problems are taken; that it is in the last analysis usually artificial, and that it is, generally speaking, expensive in student time and from the financial standpoint.

A third variant has been the use of tests devised to measure the aptitude of individual students. A variety of these tests have been applied under many different conditions. They have been given only at entrance; at other times, they have been given at stated periods through the year. It is safe to say that they are always

given subsequent to the matriculation of the student. Under these circumstances, the results, when negative, are directly opposed to the judgment of experienced admission officers and to the results of entrance examinations, either when given by the College Entrance Board or by the institution. If the measurement technique is largely adopted over the period of the first year, it is quite apt to be in conflict with contemporary grade records, which when interpreted by administrators with broad experience, still remain the most definite index of ability, interest, enthusiasm, and probable accomplishment. There are frequent occasions on which the students are subjected to tests, measurements, interviews, etc., under unfavorable conditions, and such circumstances should be avoided. One educator who has had teaching experience and contact with students in several institutions where this method has been tried goes so far as to say that, with increasing familiarity on the part of student bodies, the test type of educational measurement has degenerated into a form of contest in which the student, according to his mood, will either coöperate with the examining officer or deliberately misinform him for the sake of creating the impression the student most desires.

A difficulty of the measurement method of attack lies in the fact that it is diagnostic and lacks opportunity to be corrective in any but a detached way. The chances that it will be untimely are about as good as those that it will be timely. There is a very definite feeling among teachers of engineering subjects that there has not been developed any educational measurement which will indicate exactly the presence of qualifications for this or that specific branch of engineering, that these tests do not even constitute a litmus paper which will determine inescapably whether a given student is excellent, indifferent, or poor as professional engineering material. From an analysis of opinions expressed by many different persons in the discussion of papers on the subject read at S. P. E. E. conferences, I think it is safe to say that engineering educators in general hold tests to be of experimental value only and in no sense a suitable substitute for the carefully measured opinions recorded in the grade records of the student. Establishment of special groups within an organization for the development of test procedure has been supposed to create the necessity for production of results which would be a reason for the continuance of such efforts. There is a more or less definite impression in connection with such tests that there are times when more emphasis is placed upon statistics which will prove the validity of the tests than upon development in terms of its value for a given student. In the final summation, results of such testing show, in the opinion of many, that the

test type of investigation claims credit for developing evidence of characteristic behavior which is a quite natural result of the regular routine and sufficiently obvious without the use of test material.

This seems to suggest the thing which is the first requirement of orientation for the engineering student. It must be done early and must be used in a setting which is an entirely natural arrangement, one in which the student will have frequent and constant association with persons who are making orientation a major objective of their work. The material should suggest the attitude and tend to duplicate the environment of the professional engineer. Furthermore, some particular part of the program should symbolize and typify engineering to the student; provide some tangible evidence that he belongs to its novitiate. Every student should be subjected to an orientation program. It should be just as effective for the very able as for the delinquent student. Such an arrangement will provide an opportunity to study the individual student in all his various moods and give him a chance to demonstrate his capacity under varying conditions. The importance of this particular phase of orientation work should not be overlooked. Information gained under such circumstances may be of vital importance to the welfare of a student. Under these limitations, orientation is indicated as a definite part of the freshman teaching load, and I believe may be most successfully related to engineering graphics courses.

As a beginning, let us summarize the opinions of several leaders in this field of thought. H. P. Hammond, Director of Summer Schools for the Society, says: "As I see it, the drawing teacher has both a great opportunity and a great responsibility. He is generally the first man in the engineering faculty who has any contact with the freshmen, unless the school happens to provide a separate orientation course. Whether it does or not, the work of the drawing department gives the student the first introduction to the realities of engineering studies, and whether there is or is not a separate orientation course, one of the major functions of drawing instruction, I believe, is orientation to engineering. It is possible, through the drawing work, either to do an excellent job of orientation or a wretched one."

And further, as to the usefulness of drawing training as a general help in engineering education programs, may I add the words of Dean F. DeR. Furman:

"There are, however, certain basic and essential relationships that must exist between engineering drawing and the engineering curriculum in all college work. We may be guided in presenting these relationships by starting with frequency of subsequent use of the thing taught and leading up to other elements in the course

that give technical knowledge which will enable the graduate to use his learning in new and novel situations that cannot be handled by uneducated men.

"All courses in an engineering curriculum, at one time or another, call for presentations and arrangement of work that will give evidence of drafting room training. Nowhere in the engineering curriculum is the lesson of an accurate, neatly *finished job* so much the object of the course as in engineering drawing. The student is thus held down to commitment of exact detail from which there is no argumentative escape. It is not only in training in precision that we may find gross errors, but in the reasoning and judgment of students whose drawings clearly indicate such deficiencies to the observing instructor. It is not only the non-drawing instructor who in general has failed and failed lamentably to appreciate the lessons that may be learned from a proper course in engineering drawing, but investigators of engineering curricula who have labored at great length and yet have left engineering drawing off by itself and disconnected in an otherwise well-coördinated picture."

W. E. Wickenden, in choosing a text from which to preach to engineering drawing teachers several years ago, selected the list of such a teacher's duties presented by the Committee of the American Council of Education. From that list, he chose four which have a direct bearing on the work of the drawing teacher related to the problem of orientation. They are: (1) Coöperates with colleagues in maintaining morale and in administration. (2) Discovers significant relationships among thoughts and things. (3) Develops a coherent vision of progress. (4) Creates tools that make realization of the vision possible.

President Wickenden in the same address states that "teachers of graphics have a larger responsibility than they have accepted for the entire educational process as it relates to form and space." A little later, he develops the thought that "one of the big personal problems of the teacher of engineering graphics is that of finding an adequate field for his own personal initiative," and he proceeds by considering briefly three such collateral fields: (1) the personal counselling and guidance of students: (2) teaching, research or practice in technical fields closely related to the fundamental work in graphics, such as mechanism and machine design, graphic statics and structures, etc.; and (3) the study and teaching of the æsthetics of design. He then states that "the teacher of graphics occupies an exceptional position in relation to new students. The drawing teacher is the first contact point in college with the distinctly technical and professional side of the student's work. For many students, his subject represents the first real test in the stu-

dent's experience of precise, objective standards of excellence and of economy of time and effort in planning his work." A little further on, President Wickenden outlines what to me has always seemed a very attractive engineering and educational procedure for freshman students. "The major problem of the freshman is that of planning his work efficiently. Nearly all that we require of him could be covered in an 8-hour day under good management. Would it be better to put all our freshman work on an all-day time schedule, provide each student with a regular work place under the continuous supervision of a definite department, and devote our major effort to efficient planning and execution of work? The present plan is defended on the ground that it trains the student to work independently. I question that—does it not merely throw the student overboard on the plea of teaching him to swim? Why try to teach independence before one knows what efficient work is?"

Continuing, he suggests that, "If this plan were to be adopted, a *properly staffed* department of engineering drawing might be almost an ideal supervisory force for the freshman year. Each student would have a drawing desk for his headquarters. Two class sections, about fifty students in all, might occupy a room under one supervisor, who would also be their teacher of graphics. Teachers of mathematics, chemistry, English and the like would teach much as at present. Every teacher of graphics, under this plan, would need to have many of the qualifications and interests of a high-class personnel man. He would need to be skillful in diagnosing causes of bad adjustment. He would need to know a good deal about the work of all other freshman departments. He should have staff assistance from a real educational clinician, someone who could find out what is specifically wrong when an apparently bright boy is doing poorly. Given some such arrangement, we might greatly reduce freshman mortality and send on to the Sophomore year students who know how to make their work count. There would still be three years to train the student to work under his own direction. The battle of morale is largely won or lost in the freshman year, and the teacher of graphics is in the best position as strategist, both in his contact with the student and in the objective character of what he gives the student to do. The first real interpreter of the profession most engineering students meet is the freshman teacher of drawing."

"My final point," he says, "is, confessedly, the most vague and idealistic of all, namely, the responsibility of the engineering teacher for outguessing the future in the development of the engineering profession. If the profession is to gain in public responsibility and influence, it will be almost wholly because of the qualities of the men it enlists."

Let us, then, in this discussion of drawing as an orientation subject, consider some very recent conditions. In the years that have passed, engineering drafting room policy has been affected largely by two facts, (1) the large supply of foreign trained engineering graduates available and eager for drafting room work, and (2) the fact that the necessity for making tracings for producing blue prints rendered it economically feasible for a concern to hire high school graduates and offset the cost of training them as draftsmen and ultimately designers by the useful work they could produce in the form of linens. These two things produced an economic condition with which American college graduates have not cared to compete.

The present fixed immigration quota must in the end seriously affect the number of young foreign engineers who will be available for drafting room work.

Modern developments in the method of making tracings are such as to make it impossible to recruit drafting room personnel from promising high school material and to build this material up to the point of an effective engineering draftsman through the corporation school processes and technical night school education. This leaves the inference that drafting room organizations must in the future be recruited from our college graduates. This tendency will be supported, for the present at least, by the very large supply of material of this type which is available.

Another objection to this method of entree to the engineering profession has been the inescapable fact that men of outstanding ability do become submerged in the drafting organization. Many college students feel that when they enter the drawing room, they are in a dead-end position. This is not always the case, as there are many successful men who have started their careers in the drawing room. Now, frankly, while the two causes mentioned in the beginning have tended to deter the young engineering graduate from entering this field of engineering endeavor, the one last mentioned has been much more of a negative influence. May we emphasize this by quoting from a letter written by a practicing engineer of wide experience, a keen thinker on all of the many problems affecting the welfare of engineering graduates. It expresses the point of view of the engineering educator in general.

"The material on the subject of drawing as an orientation subject has been studied with great care.

"You do not mention one phase of drawing and engineering office practice which has contributed much of the attitude of the American engineering graduate toward the drawing room. A friend of mine expressed the thought almost thirty-five years ago

in the following words, 'When you are in the drawing room, you meet nobody, you make no new friends, you lose the friends you have.'

"Designing engineers are supposed to be omniscient and to know everything about the machine, instrument or structure which they design. They are occasionally lucky enough to watch but are not allowed to take part in the erection. When the machine is operated and tested in the field, the designing engineer is seldom present. Operating and test experience is transmitted back to the general superintendent of the plant, rarely reaching individuals actually concerned with original development. When the next similar machine is designed, such vital experience gained on the old machine cannot be utilized, and the designing engineer or draftsman is sneered at for lack of progress.

"If the American manufacturer would wipe out the sharp line between the engineering office and erection, field, and testing work by allowing the engineer who has designed the machine to follow it up and be with it until final experience has been gained, graduates would be much more willing to go into the drawing room."

What if any answer is there to these suggestions? Let us turn to the present attitude of industry as evidenced in a paper presented before the Drawing Division of the S. P. E. E. at the Cornell meeting.

"The need for men with such advanced training (in drawing) is apparently recognized in industry, and the time seems to be at hand when a larger importance must be given to that section of design engineering which we have heretofore classified as the drafting room. The student engineer should realize that the drawing board is as much a part of his equipment as the slide rule, and he cannot hope to obtain the utmost success in designing if a large part of the work connected with the development of his problem is delegated to some one who has to be given constant attention to see that the proper engineering consideration is given in all details.

"When it is realized that every component part in a mechanism must be given careful engineering consideration as to material and method of manufacture, even to the apparently small detail of fillets, it would seem the student should be trained to appreciate that a very large proportion of engineering consideration is applied when a design is being constructed on the drawing board.

"The educator must, however, assume a very important rôle in this effort. It is not going to be easy to eliminate the aversion which technically trained men have had to drafting rooms.

"The educator's part will be in appreciating the requirements of industry for the inventive type of designing engineer, and train-

ing the student to prepare drawings which will convey to the manufacturing departments complete engineering information in manufacturing language so that his design may be realized not only in operating efficiency, but in an economical manner. *Industry's part in this program must be that of providing opportunity for these engineers' progress in their profession, whether the major portion of their time is occupied at a drawing board or making calculations and sketches or supervising others who put this information into shape for production.*"

As an evidence that this advanced viewpoint is in the way of achievement, may I quote the words of the engineering personnel man of another large industry.

"As our engineering department is organized, the drawing board has pretty nearly become the focal point of engineering deliberation. It is not uncommon to note a group of mechanical and electrical design engineers, application engineers, manufacturing engineers, supervisory engineers, shop foremen of machine or assembly sections, tool supervisors, salesmen, service engineers, art directors, materials engineers, cost accountants, production men, inspectors, storekeepers, shippers, and routing men gathered around a drawing board, discussing problems of design, manufacturing cost, operation, maintenance, erection and application.

"It is our contention that an ambitious man subjected to this environment can hardly help but develop into an efficient engineer or absorb the knowledge which will enable him to fill a responsible position.

"We give considerable thought to breaking down the barrier that the draftsman still imagines exists between himself and the engineer. We are changing the organization so that a good draftsman will be pretty nearly on the same level as an experienced engineer.

"This is being accomplished by organizing the engineering department into divisions, and having certain engineers and draftsmen work as one group. This arrangement enables the draftsman to become more familiar with the problems of the engineer, and the gap between them is being narrowed. Even now, in some divisions, engineers are doing drafting work, and draftsmen are doing engineering work, in order to expedite the design of apparatus and the solution of certain problems.

"And what do these men specify as desirable attributes? First and foremost, comes education. We are constantly on the lookout for engineering college graduates to work in our drafting departments. Thirty-eight per cent of our draftsmen have a college degree. Forty-two per cent of these college graduates are American trained; the others are foreign trained.

"Experience comes next in importance. If a man has spent some time in the shop, working on machine tools, or has spent his summers while going to school in a machine shop, we know he will be reasonable in what he puts on a drawing.

"Personality is another important point. Men who wear well with those with whom they come in contact, who can take criticisms and suggestions in the proper spirit and who can coöperate, are desirable additions to any drawing room.

"The question of adaptability must also be given consideration. It is essential that a man have the ability to conform to new conditions and the new engineering system of his prospective employer."

The discussion indicates the environment to which our future engineer possibly and most probably will have to adjust himself and for which his four-year educational career must needs be a preparatory period. Our conceptions of orientation, of course, must envisage both the preparatory and permanent phases of the student's life.

Now, the students who are to be submitted to this process are curiously alike. Every man-jack of the crowd has decided that he is not attending school to learn to be a draftsman, and that to develop any marked skill along this line may almost certainly inflict that particular form of damnation upon him.

If these things, then, represent the present status of our problem, what ideals should motivate the construction of a course to meet the requirements indicated? In engineering practice, as President Wickenden suggests, it is no longer sufficient that a structure or a machine satisfy the requirements of technical formulæ. This, of course, will always be prerequisite. But the world today demands that engineering achievement shall catch and express in permanent form the emotional inspiration that lies behind great planning and great doing. Our public today demands not only the comfort of service which comes from completed engineering projects, but asks for a reflected part of the thrill of their creation. We must comply with this demand to achieve the full share of recognition to which the engineering professions are entitled.

Engineering education can never be otherwise than an integral part of engineering practice. Course content can no more be restricted to formula than achievement will satisfy on the basis of formula only. A group of students, filled with the desire to build magnificently, to create splendidly, or to discover unknown principles which will increase human happiness, will not be satisfied with a course content which, though perfectly coördinated, yet does

not give engineering education an opportunity to display the art of inspirational development. The meticulous drill elements will be gladly endured if the content affords and creates an opportunity for expression, at least between teacher and student, of those things which the student longs to do. Such things will rarely, if ever, come to the surface in mass contact, and course content which is based upon mass teaching alone will not then, afford an opportunity for this major requirement of our teaching.

Nothing so tends to fix idealism as a component of character as opportunity to express and discuss that idealism with others. In effect, the process becomes a pledge. If, in beginning courses with young engineers, their consuming enthusiasms can once be cast in the mold of verbal expression, they will thereby be more deeply and more indelibly impressed in the character of the engineer, and that that character will show through every achievement of his later life.

Dean Sackett, of Pennsylvania State College, says, freshmen find it difficult to break away from the old rule-of-thumb thinking or the formula method of doing problems, and a period of adjustment is often necessary before the student finds himself in the new engineering environment. In his opinion, descriptive geometry offers or creates the best opportunity to advise with the student who is laboring under this difficulty. Its study creates an early opportunity to confer with a student who does not have a working imagination in order that he may understand the significance of this attribute and its bearing on certain phases of engineering education and engineering practice.

Hence, in the process of working out such an idealistic teaching program, we might give a course in drawing and descriptive geometry, so correlated as to make the theoretical principles of geometry serve as an explanation of the practical steps taken when making an engineering drawing, and the nature of the teaching material would be such as not to encourage the weakness Dean Sackett has indicated. The teaching process would be divided into four distinct steps.

First, homework preparation in which the student devoted his time to the study of material or text assignments covering a definite topic in the course outline. These assignments would be prepared and illustrated so that visual imagery of the material would be encouraged by showing the student pictorially the same data presented to him in written form. In view of the fact that little learning is accomplished without some application, each assignment would include very elementary problem solutions involving the application of the various lesson points. This should provide the student with "acquaintance" with the particular topic.

Second and following this, a demonstration-lecture period covering the same data which had been studied by the student at home. In this lecture, the fundamental principle would be demonstrated by the lecturer, and the student should, as largely as possible, follow the actual space constructions and relations by reproducing them accurately in model form. This sensory space experience should be a powerful influence in the development of a knowledge of spatial relationship. In addition to his actual space construction, further drill work in actual graphing would be obtained by having the student draw the necessary graphs, step by step with the instructor as he reproduces the space construction. This should develop the student to the point of a "working knowledge" of the topic.

From this recitation period should be taken regularly some short period of time to place frankly before each group, conceptions of the obligations of engineering and the attributes of an engineer, relating exposition to the daily events and requirements of student life and tying illustrations to the material and demands of the drawing course. Include such topics as the following: (1) Orderly collection of data. Lesson assignments properly kept. (2) Meeting obligations—punctuality. Completing work assigned in required time. (3) Conferences. Where to seek them. How to conduct oneself in consultation. (4) Standard of achievement. Good, bad, and indifferent work related to personal attainment. (5) Personal responsibility to school, to department, to home. (6) The worth of our own knowledge. Value your own opinion in a group discussion. (7) Jumping at conclusions, factors of safety, caution. (8) The relative importance of social obligations. Balancing the time budget. Fraternity rushing periods. (9) What an engineer does when he leaves a job. Leaving things in order against failure to return. (10) What typifies the bigness of my profession. Attitudes in class. (11) Respect for the opinion of others. Different solutions of problems. (12) The beginnings of personal professional prestige in unusual solutions of problems. (13) The value of the other fellow's point of view. Tolerance. Patience. (14) The necessity for attacking large problems and building of small element machinery. (15) Self-starters. Don't become discouraged—get your head in your hands. General long time planning. Check up on your grades. On the general state of completeness of your work. Find time to do the extra work; and a similar series the second semester.

Third, a first laboratory period in which the student would solve problems illustrating variations of the fundamental data studied in the homework and lectures. This phase of the course

would aim specifically to develop analytical thinking and self-reliance through individual work. In this period, the teaching method would take the form of individual attention to the personal difficulties of each student. It should advance the student to "familiarity" with a topic.

Fourth, a second laboratory period devoted to the development of the necessary manipulative skills, knowledge of correct representation of engineering data, and familiarity with the conventional methods of graphic specification. In addition to the application of pure theory covered by descriptive, practical application would be covered in the drawing, and the student given elementary practice in the use and manipulation of the slide rule.

The breadth of the student's training would be increased by the introduction of reading problems in which the student by various devices indicated to the instructor that he understood the principles of graphic representation. This would enable the student to cover a much larger number of drawings than if he himself had to draw each particular object. In the problems in the final phase of the course, the reading element, the theory element, the representation element, and the slide rule practice would be brought together in a series of engineering drawings of typical projects.

For the further development of self-esteem and professional spirit of engineering students during the formal educational period of their lives, there might be displayed during the progress of these laboratory courses a series of bulletin board posters carrying portraits and biographies of persons prominent in engineering with excerpts from their writings, emphasizing the value to engineers of training in engineering drawing.

The achievements of such men, the story of their mastery of themselves and their difficulties, and the many human things associated with them in their lifetime would undoubtedly prove sources of inspiration to struggling and discouraged students.

These posters might include illustrations of particular projects with which these men were connected and which promoted engineering progress. Material such as this shows clearly that in the past, success for some person has been built upon a type of engineering effort (drafting room employment) that is to become a necessity for many of our future graduates. In the case of many who aspire to greater success than that which they will probably attain, it will have a tendency to create the sort of mental ease that will mean increased happiness and coherence in engineering life. The complete program envisages the portrayal of a different personality once a week over a period of four years before the material so used may be used again. This means 160 to 200 different per-

sonalities from various fields of engineering. These should be divided into two groups.

The first group would consist of persons well along toward the end of their careers. The reactions of students might be affected by the human tendency to say that such success was possible only in an earlier day. To make the material more effective, it would be necessary to associate it with a second group of younger men who are in the process of working out similar achievements at present. This group should include men from the alumni of the institutions displaying the posters. The advantage lies in direct connection between the student and his own prospects. The work of such men could not be illustrated by complete biographies, but perhaps better by placing before the students sets of drawings or printed material in connection with some project which the younger man is directing. In addition to the first two selections, each institution will plan to show examples of the work of its faculty members when they were in the student phase of their careers and, if possible, drawings or illustrations of engineering work with which professors may be connected in a consulting or research capacity. This should promote reasoning from type of work to personality students admire and respect. To bring the project to the point of personal application and as a spur to start the development of standards, when a student develops outstanding ability in drawing in class, we might insert a display of his work on the bulletin boards together with such material as has been outlined above. Juxtaposition of such material tends to create, first, a respect for achievement based on elementary engineering training; second, a dollars and cents motivation for it; and third, the work of the faculty members gives the student a direct reasoning association between excellence of student work and respect for the instructor. The final introduction of the student work has the effect of persuading the student that achievement of the standards required is possible for his own classmates, and hence for him. The whole general scheme would assume the aspects of an ascending stairway of accomplishment. The type of material which might be used in such displays was well illustrated by the historical displays at Cornell. These displays were made particularly for this purpose under the direction of the Executive Committee of the Division of Drawing and Descriptive Geometry of the S. P. E. E.

We might add a concentrated week during the course which would afford an opportunity to catch up the whole process as it has been analyzed and carry it more nearly to its ultimate possible form and attempt to organize the class into an organization which would function with at least some resemblance to an engineering drafting room in which outstanding students would be given the

posts of leadership. There are many advantages to be gained from this. Among other things, it would afford an opportunity to show men the advantage of working together in a group, a chance to work under the supervision of some one not invested with the prestige of the instructor, to work through the man directly responsible for results. It would teach coöperation. Freshman students need the conception of the ensemble to round them out. It would offer an opportunity to determine whether or not certain things are possible. Can a student, fairly promising at the start, be developed at a sufficiently faster rate of speed so that at the proper time he may be entrusted to guide the work of a small-sized group of others? Can he be trained beyond the possibility of the average of the class and given instruction which at the finishing period he may impart to the members of his group and thus raise the whole level of the class beyond the point to which they can be carried if the whole responsibility is laid upon the ordinary course of teaching? If this fundamental conception of teaching elements and principles to a set standard is sound, and if the promising student can be developed as indicated to a relation approximating that of a squad boss in actual drawing rooms, can the teacher move into the same relative position as that occupied by a chief draftsman and have the class function in an orderly and efficient manner without regarding the necessary amount of production or the relationship between themselves and others as a hardship or oppressive experience? These things would involve a test of the drawing course as much as a test of the students. These things would involve the realization and the discovery that all drafting work is not smooth sailing, and the experience would most likely be a valuable one. It might help the student to weather the stress of circumstances when things on the job do not run smoothly. It may impress upon him the necessity for a little forward thinking in connection with his work. It may help him to appreciate the value of a great deal of care when his work has to be made to key up with and fit into the work of others and of the importance of checking and counter-checking. It may make clear to him the increased possibilities of five men working as a unit as opposed to five men working as individuals. It may help him to see that it pays to be wholeheartedly a member of a group devoting its whole energies to a common end. He may discover that someone else can and will help him solve his difficulties. He will have the experience that comes from being able to enter a serious consultation and add his bit to the knowledge required to meet the problem of his little group. There are decidedly a great many incidental advantages which may come of a concentrated week aside from the mere matter of making a few drawings.

COMPARATIVE STUDY OF THE CIVIL ENGINEERING CURRICULUM IN THIRTY-FOUR INSTITUTIONS

By M. O. FULLER

Associate Professor of Civil Engineering, Lehigh University

The Wickenden study of engineering education (under the auspices of the Society for the Promotion of Engineering Education) showed the development of well-nigh standardized curricula in the main professional fields. In the four years since that report was issued the demands of new technical material for inclusion in our already overcrowded courses of study have continued and the plea of President Wickenden and his associates for a more liberalized curriculum has led to curtailment of the time devoted to technical subjects. The perplexities which consequently confront engineering faculties have led to this comparison of the civil engineering curricula of thirty-four institutions—seventeen on the Atlantic seaboard, thirteen in the middle west, and four on the Pacific coast. This comparison has confirmed the standardization mentioned, together with large deviation from the norm by some schools. The competition between engineering schools is likely to be increasingly severe and it is important that we study our plan carefully, justify all our deviation from accepted standards, and unhesitatingly break with that standard where advance seems to us possible.

Lehigh University revised her curricula in 1926 while the Wickenden investigation was in progress and by her action anticipated the S. P. E. E. conclusion that engineering education should be generously liberal and not narrowly technical. Our civil engineering students devote a larger proportion of their time to subjects of a generally collegiate nature than do their fellows in thirty other of the thirty-four colleges under scrutiny. This is indicated on Chart 1 where is shown the proportion of time devoted to engineering (drawing, highways, railways, structures, hydraulics, electrical and mechanical engineering, etc.) and to liberal art subjects (mathematics, English, physics, chemistry, geology, economics, social science). On the average these thirty-four civil engineering curricula, devote 46.6 per cent of their time to liberal art subjects, 53.4 to engineering: the Lehigh figures are 54 and 46 per cent, which is exceeded by only one school. Of the seventeen schools in

the eastern group eight give somewhat more, and eight somewhat less than the average time to humanistic subjects.

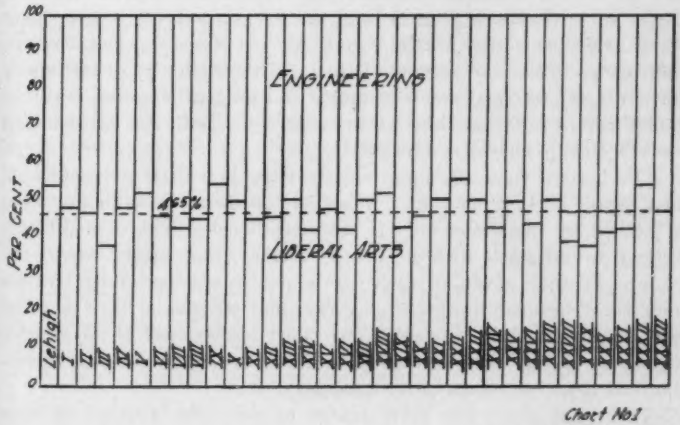


Chart No.1

The group of universities in the central section of the country, thirteen in number, show seven above and six below the average line, while of the four far west colleges, one is on the average line, one above, and two below. Studying the other aspect, namely the engineering work, the average is 53.4 per cent with fourteen out of the thirty-four giving more than the average, thirteen below the average, and the remaining seven close to the average line.

The second chart shows two deviations of the Lehigh curriculum

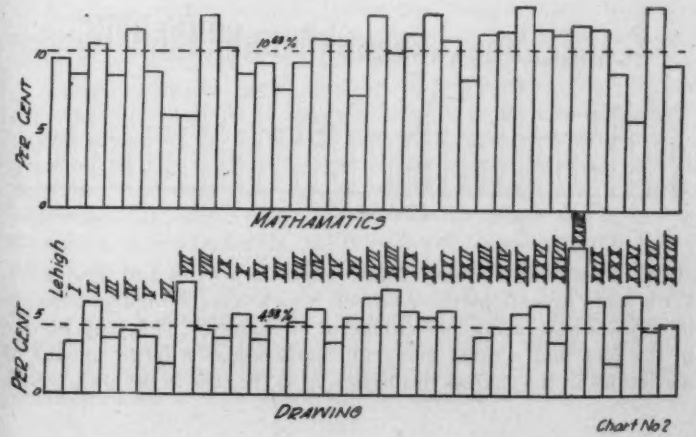
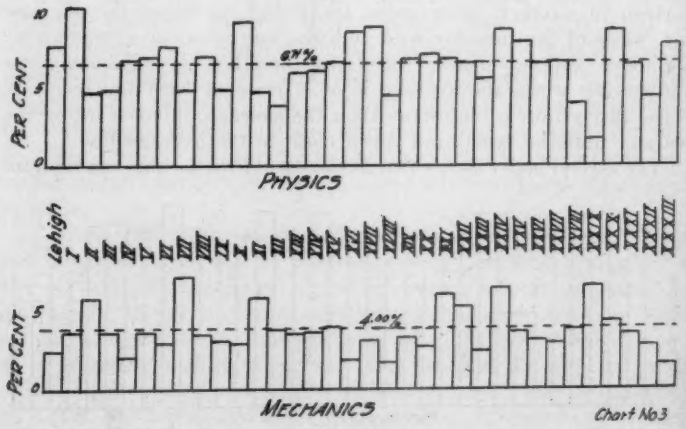


Chart No.2

below the norm which must call for justification. We give ten per cent of our time to mathematics while the norm is 10.68 per cent. This signifies a difference in method of instruction since in subject matter we cover more ground than the average, giving a large part of one semester to differential equations. It is to be noted that the institutions in the mid-section of the country, with all but one above the average line, are much stronger in the mathematics training than those in other sections of the country. Both the eastern and western group vary considerably.

The Lehigh time allotment for drawing is a little over one-half the average of 4.58 per cent. Whether the course is sufficient must be judged by inspection of our students' work. This is a difficult subject to tabulate with accuracy. In a great many cases, the amount of time given to drawing is not shown, as many courses such as structural design, highways, and railroads have a great deal of drafting room work. The chart shows only those courses which are listed as drawing in some form or other such as mechanical drawing, descriptive geometry, etc.

The third chart has been drawn to show the amount of time



given to two rather closely allied subjects, physics and mechanics. With some exceptions those schools which have a high percentage in physics have a low percentage in mechanics. This may be due to the fact that a great many universities give a large amount of mechanics in the courses in physics, as is the case in my own school.

The fourth chart shows a far from standardized condition with regard to two fundamental humanistic subjects, English and economics. It is probable that this indicates a transition period with change to a new standard more in conformity with the S. P. E. E. recommendations—the indication is that about one-half of the universities have rather low time schedule for English. In some places English is required but no credit hours given for the work. The Lehigh standard in English is evidently too low and we are considering ways of improving our students' ability in writing and speaking.

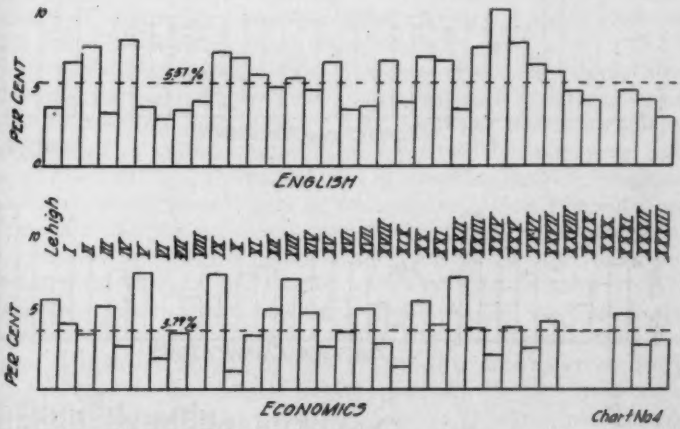


Chart No 4

The engineering subjects, surveying, railways and highways, hydraulic engineering, sanitary engineering, and structural engineering, are shown on charts 5, 6, and 7.

In surveying, the trend seems to be below the average of 5.69 per cent, due no doubt to the belief that only the elements of surveying should be given, in that real work in surveying is only by practical work in the field. It would be interesting to know what the trend was some time ago, before the country was as thickly populated. It will be noted that the Prairie States are in general stronger and also that state institutions and those near large metropolitan centers are rather strong in surveying courses. The Lehigh low time allotment is due to a policy long held that only basic theory with a minimum of drill in instrument handling is essential. Some in the staff are beginning to question this theory and advocate a second course for civil engineering students which would stress precision as well as extend the ground covered.

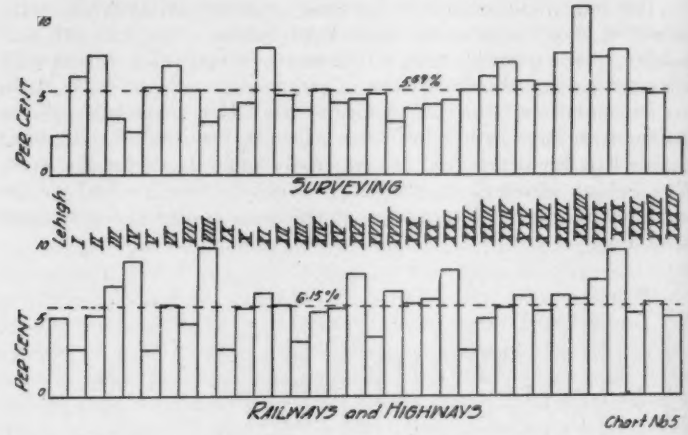


Chart No5

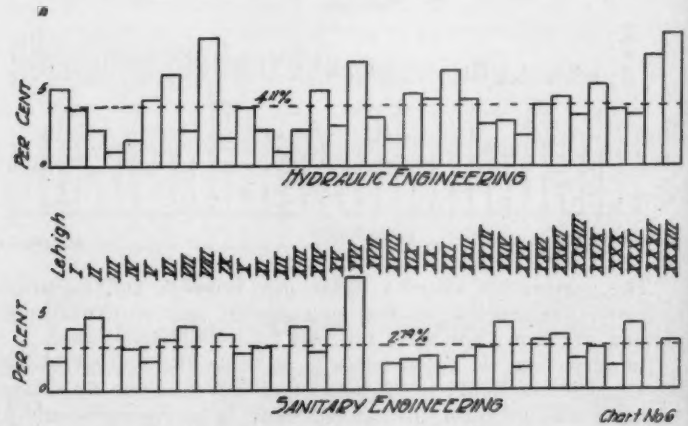


Chart No6

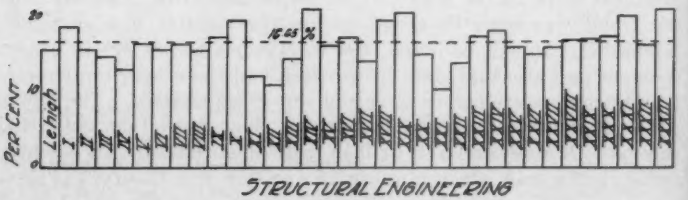


Chart No7

The chart of railways and highways is of interest, in that somewhat the same trends are shown as in surveying. Here there is also some overlapping, in that those low in surveying are high in railways and highways.

The amount of time given to hydraulic engineering is below the average of 4.11 per cent in nineteen universities. Those which are above the line are in general near large centers or potential water power developments.

The question of sanitary engineering is one of vital importance in this age. Some few institutions have courses in sanitary engineering. But as far as the time devoted to sanitary work in regular civil engineering courses goes, the majority of the universities fall below the average of 2.79 per cent.

The civil engineering curricula in most of the universities have been and no doubt will be for some time, giving a major portion of time to structural engineering. With 16.65 per cent to structural engineering as against a total of 18.74 per cent for surveying, railways and highways, hydraulics, and sanitary engineering, is shown the trend at the present time in this country. It will be noted on the chart that the variations from the median line for structural engineering are less pronounced than in any of the other branches. Some universities do not include advanced work in structures in their four years curriculum, being content to give the time to the fundamental courses. Those students who are particularly interested in advanced structural work are urged to take an extra year's work. This has been largely our own policy.

Another form of chart has been used to show the percentages of hours devoted to civil engineering, electrical, and mechanical and non-engineering. This chart shows that nearly all the thirty-four universities give some time to electrical and mechanical courses, ranging from zero to about twelve per cent. The spread in non-engineering is from forty to sixty per cent, and in civil engineering from fifty to sixty-eight per cent. It will be noted that Lehigh University is nearly in the middle of the group.

This survey has shown that in general the Lehigh curriculum conforms to the accepted norm for American technical schools, except for apparently abbreviated programs in drawing, mechanics, English and surveying. Rather pronounced increase of time allotment above the average are to be noted in liberal art subjects, physics, economics, and hydraulic engineering.

DISTRIBUTION OF TOTAL TIME IN PER CENT IN CIVIL ENGINEERING CURRICULUM IN THIRTY-FOUR INSTITUTIONS, 1934–1935

	L/--high	I	II	III	IV	V	VI*	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII
Surveying	2.66	6.66	8.04	3.78	2.82	5.84	7.28	5.63	3.62	4.46	4.82	8.60	5.30	4.31	5.74	4.87	5.10	5.92
R. R. & Hwy. Engr.	5.34	3.20	5.55	7.55	9.15	3.24	6.25	5.00	10.13	3.18	6.03	6.75	5.96	3.70	5.74	5.97	8.27	3.94
Hydraulics Engr.	5.34	3.94	2.47	1.89	2.82	4.54	6.25	2.50	8.70	1.91	3.92	2.45	1.99	2.45	5.10	2.78	7.00	3.29
Sanitary Engr.	2.00	4.26	4.94	3.78	2.82	1.95	3.65	4.37	0.0	3.82	2.41	3.06	0.0	4.31	2.55	4.17	7.65	0.0
Structural Engr.	16.00	19.25	16.05	15.10	13.38	16.90	16.15	16.85	15.95	17.83	19.90	12.28	11.25	14.81	21.60	16.70	17.80	14.50
Sum	31.34	37.31	37.05	32.10	30.99	32.47	39.57	34.35	38.40	31.20	37.08	33.14	24.49	29.58	40.73	34.43	45.82	27.65
Electrical	4.00	3.52	1.85	3.78	5.64	3.90	3.65	2.50	0.0	1.91	2.71	2.45	3.98	4.93	5.10	4.17	2.54	3.29
Mechanical	2.66	3.94	2.47	3.78	7.74	3.90	5.74	1.88	0.0	1.91	2.41	3.06	5.95	4.93	2.55	2.08	2.54	3.29
Sum	6.66	7.46	4.32	7.56	13.38	7.80	9.39	4.38	0.0	3.82	5.12	5.51	9.93	9.86	7.65	6.25	5.08	6.58
Mathematics	10.00	8.90	11.10	8.80	11.98	9.08	6.25	6.25	13.04	10.82	9.03	9.84	7.95	9.87	11.48	11.42	7.65	13.16
Mechanics	2.66	3.94	6.16	3.78	2.11	3.90	3.12	7.50	3.62	3.18	3.00	6.13	3.98	3.70	3.82	4.17	1.91	3.29
Physics	8.00	10.60	4.94	5.02	7.05	7.14	7.82	5.00	7.25	5.10	9.63	4.91	3.98	6.16	6.38	6.95	8.91	9.20
Chemistry	7.34	5.42	4.94	3.78	5.64	6.50	6.25	3.75	5.80	5.10	3.61	4.91	5.30	3.70	5.74	6.95	5.10	5.26
Geology	4.00	2.70	0.0	0.0	2.82	1.95	4.17	1.88	0.0	3.83	0.0	3.06	0.0	1.84	5.74	3.48	0.0	1.97
Drawing	2.66	3.46	6.16	3.78	4.23	3.90	2.08	7.50	4.35	3.83	5.42	3.68	4.64	4.93	5.74	3.48	5.10	6.58
English	4.00	6.90	8.04	3.78	8.45	3.90	3.12	3.75	4.35	7.64	7.22	6.13	5.30	5.64	5.10	6.95	3.82	3.95
Economics	6.00	4.44	3.71	5.65	2.82	7.76	2.08	3.75	0.0	7.64	1.20	3.68	5.30	7.39	5.10	2.78	3.82	5.26
Astronomy	0.0	0.0	0.0	0.0	1.40	0.0	0.0	1.25	1.45	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Elective:																		
Technical	2.00	0.0	0.0	15.10	1.40	—	—	3.75	8.70	3.83	0.0	6.75	11.90	1.84	0.0	4.17	0.0	5.92
Non-Technical	8.00	3.70	2.48	7.55	3.52	—	—	5.64	13.04	0.0	9.04	3.68	5.96	0.0	0.0	2.78	7.65	6.58
Physical Ed.	0.0	0.50	1.85	—	—	—	3.12	1.25	—	—	—	3.06	3.98	4.93	0.0	0.0	1.91	—
Military	5.34	2.96	—	—	—	2.60	—	5.00	—	3.82	4.83	2.46	—	4.93	0.0	2.78	0.0	2.63
Miscellaneous	2.00	1.71	9.25	3.10	4.22	13.00	13.02	5.00	—	10.18	4.82	3.06	7.28	5.63	2.52	3.35	3.23	1.97
Sum	62.00	55.23	58.63	60.34	55.63	59.73	51.04	61.27	61.60	64.98	57.80	61.35	65.58	60.56	51.62	59.32	49.10	65.77

* Five years.

DISTRIBUTION OF TOTAL TIME IN PER CENT IN CIVIL ENGINEERING CURRICULUM IN THIRTY-FOUR INSTITUTIONS, 1934–1935

	XVIII	XIX	XX	XXI	XXII	XXIII	XXIV	XXV	XXVI	XXVII	XXVIII	XXIX	XXX	XXXI*	XXXII	XXXIII	Aver.
Surveying	3.55	4.23	4.41	4.96	5.59	6.60	7.52	6.16	6.07	8.20	11.25	7.85	8.34	5.60	5.36	2.42	5.69
R. R. & Hwy. Engr.	7.10	6.34	6.61	8.50	3.10	5.27	6.01	6.85	6.07	6.84	6.65	7.85	9.85	5.60	6.32	5.36	6.15
Hydraulics Engr.	1.77	4.93	4.41	6.38	4.35	2.86	3.00	2.06	4.05	4.54	3.34	5.38	3.79	3.35	7.31	8.87	4.11
Sanitary Engr.	1.77	2.11	2.21	1.42	1.86	2.86	4.51	1.37	3.38	3.64	2.08	2.95	1.52	4.48	0.0	3.22	2.79
Structural Engr.	20.10	21.10	15.45	10.63	14.30	18.00	18.80	16.40	15.50	16.00	16.70	16.90	17.42	20.70	16.86	21.00	16.65
Sum	34.29	38.71	33.09	31.89	29.30	35.59	39.88	32.84	35.07	39.22	40.22	40.93	40.92	39.73	35.85	40.87	35.40
Electrical	0.0	2.11	3.68	2.84	3.72	2.64	3.00	4.11	2.71	0.0	0.0	0.98	2.27	0.0	0.0	4.34	2.71
Mechanical	1.48	2.11	3.68	0.0	3.72	2.64	3.00	4.11	2.71	0.0	3.34	0.98	2.27	4.48	2.90	1.65	2.94
Sum	1.48	4.22	7.56	2.84	7.44	5.28	6.00	8.22	5.42	0.0	3.34	1.96	4.54	4.48	2.90	5.99	5.65
Mathematics	10.65	11.97	13.22	11.34	8.70	11.88	12.05	13.70	12.17	11.84	12.50	12.23	9.10	5.04	13.20	9.70	10.68
Mechanics	1.77	3.52	2.95	6.38	5.59	2.64	6.76	4.11	3.30	3.20	4.16	6.86	4.55	3.72	2.90	1.65	4.00
Physics	4.74	7.04	7.35	7.10	6.84	5.71	9.03	8.20	6.76	6.84	4.16	1.97	9.10	6.70	4.40	8.10	6.71
Chemistry	7.10	5.64	7.35	7.10	5.59	3.95	4.51	6.85	5.41	6.84	6.25	6.37	7.58	6.43	4.40	6.50	5.82
Geology	2.97	2.11	1.48	2.12	1.86	0.0	2.26	2.06	2.03	1.32	2.08	0.0	2.27	2.22	1.43	2.70	1.95
Drawing	7.10	5.64	5.15	5.67	2.48	3.95	4.51	5.48	6.08	3.64	10.00	6.37	2.27	6.70	4.40	4.86	4.58
English	7.10	4.23	7.35	7.10	3.72	7.92	10.52	8.20	6.76	6.34	5.00	4.43	0.0	5.04	4.40	3.22	5.57
Economics	2.97	1.41	5.88	4.25	7.45	3.95	2.26	4.11	2.71	4.54	0.0	0.0	0.0	5.04	2.90	3.22	3.79
Astronomy	2.37	0.0	0.0	1.42	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.03	0.0	0.0	0.0	0.32
Elective:																	
Technical	3.55	5.54	4.41	2.84	—	2.64	—	—	6.76	4.00	3.75	—	—	3.35	11.74	9.70	4.02
Non-Technical	0.0	4.23	—	7.10	—	5.94	—	—	0.0	4.00	—	14.45	12.10	3.35	2.90	0.0	3.54
Physical Ed.	4.15	2.82	—	1.42	4.96	—	—	2.74	—	—	1.66	—	—	—	—	—	1.12
Military	—	2.82	—	—	4.96	—	—	—	2.75	2.76	2.50	2.95	—	—	—	—	1.65
Miscellaneous	9.76	—	4.41	1.43	11.21	10.55	2.26	3.49	4.75	5.46	4.58	1.48	4.54	8.20	8.57	3.49	5.20
Sum	64.23	57.07	58.35	65.27	63.23	59.13	54.12	58.94	59.51	60.78	56.44	57.11	54.54	55.79	61.25	53.14	58.95

EXTRAVAGANT DEMANDS FOR SOCIAL SCIENCE IN EDUCATION

By LEWIS E. AKELEY

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From some letters received concerning the first article published in the JOURNAL under the title "Extravagant Demands For Social Science in Education," it appears that rather too much was left for reading between the lines. Now some things must not be left to be read between the lines in an article which so decisively antagonizes some very strong current tendencies. Social scientists are pretty strongly addicted to the sophistical habit of taking any current social consensus of opinion, if it be strong and well nigh unanimous, as authoritative for their "inarticulate major premises." This strongly marked tendency of almost all contemporary thinking is really the point of attack upon the Conclusions and Recommendations which were criticized in the article in question. It is just that same strong tendency toward an over-respect for contemporaneousness which will immunize and render callous to all criticism certain engineering colleges which have gone to extremes in the introduction of social and economic science into their curricula. Hence, the justification for more explicit statements of some things which were left to be read between the lines in the article which appeared in the May number of the JOURNAL.

The social scientists need and lack a way of thinking relevant to all possible fields of thought, which a competent training in physical science alone can give. Now, when this is said, it is equally true that physical scientists need and often lack a way of thinking which only a general training in scientific method and psychology is likely to give. As the engineer must deal with men, nothing human can be alien to him or to his education.

The crux of this whole matter is set forth quite clearly in an article by Harold J. Laski in Harpers Magazine, December, 1930, entitled "Imitations of Experts." Both engineering and social science specialists owe their limitations to just such causes as Professor Laski points out. Professor Bridgman, in his "Logic of Physics" felt called upon to challenge attention to the relations subsisting between the objects of modern physical science research and the mind of the researcher. Now, in all probability, the great

body of psychologists and logicians, philosophers and specialists in scientific method have never been brought to the point of acknowledging that Professor Bridgman, a physicist, has made any contribution to the science of mind. Some of them have. But the most of them, no doubt, are too strongly possessed by the spirit of what Professor Laski calls "*caste*" to make any such acknowledgment. The caste attitude deserves a very harsh name, for it is undeniably true that no one can enter into any degree of adequate understanding of the work of physics during the last twenty-five years without something very decisive happening to his mind, *pace* those ill informed people who think recent physics is crazy.

The limitations of the social scientists today require heroic treatment. The measure of the drastic character of such treatment is the absolute necessity that the social thinker completely recover from that ailment that leads him to believe that physical science has created a Frankenstein monster from which the social scientists alone are our destined saviors. Not only must that idea be cast out, but with it, its vast world of implications, many of which contemporary social thinking has never consciously conceived.

The article in the JOURNAL in May, 1935, entitled "Extravagant Demands for Social Science in Education," is not to be understood as a demand for a limitation on the amount of social science in educational programs so much as upon the kind of social thinking which such programs are sure to inspire under present conditions. All specialists are limited, as Laski claims. There is a vast deposit of experience from which men extract all the wisdom which they are able to apply to the management of their affairs. From that deposit of experience, all the knowledge of special fields is elaborated. It is not, however, true that the sum of all the contents of the special sciences covers all the wisdom which practical men are daily extracting from that treasure house of the world's accumulated experience. The whole content of science, in one sense, is more than the whole deposit of uncritical experience; in another sense, it is very much less. Because of the latter fact, the expert, just as Laski claims, needs the man of affairs to tell him where to get off and where to get on. It also follows from these considerations, that social scientists who have not learned to think in many of the ways in which physical scientists have to think, are woefully limited in their own fields. In saying this, it is not meant that the methods of the physical sciences can be passed over uncritically, into the field of the social sciences. There are differences between the two fields which must be respected. But modern advances in physical science have thrown light upon the

ways of successful thinking in all fields. One who has some critical understanding of both fields is the only one who is competent to appreciate the differences between them, and also equally to appreciate that element in modern physical science which is universal to all thinking. For example, what the contemporary physicist is learning about thinking, when critically developed in its relation to all thinking, would reconcile the long drawn out traditional quarrel between empiricists and rationalists in ethics.

It is a dangerous thing to dull the clear conceptions and sense for reality of the student of engineering by the incompetence of contemporary social thinking. It is not safe to allow anybody to teach social science to engineering students who has not, as his background, good conceptions of the advances in physics of the last twenty-five years. We may be obliged as a practical necessity, to do something of this sort until social scientists can be found who have such a background. But so long as present conditions in social thinking hold, the less social science in the engineering colleges, the better. It must be conceded that it is necessary to have some social science instruction for engineering students and also that it is desirable to have much more than this necessary minimum. But under the prevailing attitudes of social scientists, it is desirable to have as little as possible. The necessity for eliminating the limitations of social specialists in the matters under consideration should be a standing challenge to engineering college administrators. The job of the physical science specialist is to pluck the beams out of his own eye, no doubt, as a first step. However, it will never do to entrust that surgical operation to men who have such conspicuous motes in their own eyes as to make certain the destruction of that virtue of successful seeing which the ways of physical and mathematical science have revealed to the mind of the modern physical philosopher.

NEEDS OF INDUSTRIES FOR TECHNICALLY TRAINED MEN *

By E. B. ROBERTS

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Usually about June or July a great many editors and a smaller number of employers, suiting the word to the period of graduation, make the opportunity to say many a word to the college boys. They tax them for their unwarranted demands, their inordinate expressions, their lack of culture, their ill-sense of fitness, their manners, and their clothes. I feel that in general the more such have to say, the less their experience—the less their real knowledge of the type of men our engineering colleges are producing. The organization from which I come believes in the college man, and has believed in him since the earliest days. It was the custom of Mr. George Westinghouse to notice and build into his organization, his offices, his drawing rooms, his shops, and his laboratories college graduates, not only from institutions of this country, but from Europe as well. Under such conditions, now fifty years ago, came such men as the late Benjamin Garver Lamme, whose recognition of engineering education this Society honors annually; Dr. Charles Felton Scott, who is entitled to continuing recognition for his leadership in crystallizing the objectives and enriching the meaning of engineering education, and for his well known contributions to the training of engineers both in industry and in the school. George Westinghouse was the first individual to conduct, so far as I know, a college recruitment campaign. Every year since, I believe I am correct to say, the Company that bears his name has employed, proportionately, more college-trained men than any other company. Even in these bad years—witheringly discouraging as they are for college men—the Westinghouse Company has retained a proportion of its college training program. In 1933 and again in 1934, we employed sixty new college graduates, and the outlook for 1935 is at least as good as it was a year ago.

With the change in character of industry and the new demands that are thrown upon management, there are two types of men difficult to find.

* Presented at the Conference on Electrical Engineering, Atlanta meeting, S. P. E. E., June 24–27, 1935.

Manager or Supervisor Type

The first of these is the *manager or supervisor type.* It is difficult to find men to put in charge of this activity or that. The selection of men is an uppermost problem with us, as it is with most industries, right now. There is an ample number of men who know the technique of the field in which they were trained or in which they have been at practice, but when the call is for a man to take charge of the several functional groups that comprise an activity—the technical engineering, the sales negotiation, the manufacturing, and the accounting—the engineer is at a disadvantage and there are few among whom to choose.

It is a trend of industry that brings this point to the fore at this time. We are seeing many industries organize along somewhat different lines than those by which they have grown. The automotive industry has led the way. Formerly organized along function lines with a chief executive viewing his organization as composed of divisions each responsible in its field—for the engineering work, the research work, the manufacturing work, the accounting work, the sales work and the service work, now we find organizations devised more along product lines with the engineering, the manufacturing, the accounting and the sales negotiations responsible to a unit manager, whose responsibility, in turn, is for the net results of his unit from a profit standpoint. A large industry will contain a considerable number of these unit managerships. It is a new type of job and those who hold these jobs are very definitely key men of the industry. Their problem, primarily, is one of management.

Considerable study has been put upon the subject of management in our better schools of business administration, but to what extent have the enginering schools been aware of and alive to this need? Educators must not content themselves with the idea we hear so often expressed in engineering educational circles, that an engineering training fits a man to hold any position along management lines. The fact is, it does not, and in some cases, positively otherwise. The engineer is so often so completely preoccupied with his own technique that he neglects all other interests and values. His tendency often is to measure people and situations in the objective terms of his own technique, so that he fails to gage the reactions of people of every-day situations and problems. The very preponderance of his success through objective methods, limits his outlook when psychological and subjective values obtain. Those of us from practice know the situation well. Here is the engineer who has a record of success in his sphere of design. As he has gained engineering prestige, he convinces himself that he knows

all about accounting; he collides with the Sales Department because he is unwilling to be guided in his designs by what his market will take; he would force his ideas on his customers without regard to their opinions and experiences; he is unable to negotiate and adjust his relations with the shop; his costs are too high—but why go on?—his type is familiar. *One of the personnel problems today is finding the type of man who can take charge of mixed functional groups and manage his end of the business on a profit basis.*

Commercial Type

The second type to which I refer touches more closely the younger graduate. It has to do with the recruitment of the sales department. I do not feel that our engineering schools have ever been willing to recognize the commercial departments of industry as fully as important outlets for the best of their product as the design and research departments. Yet, in our organization, at least, *we conceive that the ability to perceive the application and to negotiate its use calls for just as high an order of creative ability as does the design of the machine for that application.* Let us compare. The engineer is the investigator—the creator of material values. Not always is he the best interpreter of the values he creates. He needs the promoter—the salesman. The creation of the engineer must be translated into use. It is a phenomenon of humanity that the two abilities seldom meet in the same individual. The real salesman interprets the need of the layman to the engineer—the user, to the maker. He bridges the gap between the profundity of the science of the engineer and the generalities of the public. Is it too much to say, "The engineer advances knowledge; the salesman advances progress?" Scientific progress is at the moment, in advance of the world's power to use it. It is trite in our organization to say that we know how to build more things than we know how to sell. Let us not as engineers blame the difficulty on the distributor. Distribution, as we treat of it, is also an engineer's job and, while engineering educators have recognized it increasingly during the past ten years, that recognition has not been to any considerable extent interpreted into changes of policy, curriculum or program. However, in the next social and economic stage of our country, it may well be that the greater emphasis will be here. It must be significant that, of 120 young engineers who have entered the Westinghouse Company in the last two years, 100 are entering upon sales work. Yet, with twelve thousand applications before us, we have had to sift again and again to find that 100 of the inherent qualities we seek in our potential salesmen. Too often,

I fear, in our engineering schools, the process of selection, the nature of the training, and dare I add the influence of the faculty, has forced the best of those who were called for a commercial engineering career, out of our schools of engineering into other university departments. Here again, the difficulty of the young engineering graduates, who survive to graduation, lies in the fact that they have not been led to develop that sense of those values that are not objectively measurable, but that are absolutely essential for success in this great and open field of business negotiation.

Broadening Need

Do you not find that my observation of the opportunity in this direction is supported by your experience? Do you find that those of your graduates who have attained positions from which they render a high and significant service are constantly confronted with problems of an economic, business and commercial, and human character which were not foreshadowed in any portion of the curriculum through which they were trained? Do you find that they use an entirely different technique of management in the fields of their success than is provided through the usual engineering courses?

No one of vision can doubt but that the character of industry is being transformed and that the qualities that it will demand of its future leaders are vastly broadening. Schools must prepare their students with new outlooks. Engineering education must recognize and appreciate the new environment in which it finds itself. It must prepare to serve on this higher plane. It will be tested by its ability to prepare men for engineering, industrial and public leadership. As industry gets its stride again, it will call first on the engineering schools for young men who have these qualities, but if they are not there to answer, then industry will seek them from other sources—the schools of law, the schools of business and the liberal colleges.

Looking now at the broad topic which has been assigned me and as illustration of the two points I have endeavored to make, I want to leave it clear that our industry finds the best of the engineering graduates, who are coming to us from our engineering colleges, thoroughly well prepared as to fundamentals for the technical work of engineering, research, design and development, but that we feel there is much to be desired in the way of developing more men who have not only the technical ability, but who can meet the requirements from a business and management standpoint as well. Last winter our Associate Director of Research, Thomas Spooner, presented before the American Institute of Electrical Engineers, the results of a study which he made of a number of

young engineering graduates who had passed through his charge during the recent years. While the men on whom this study was based were all of what we call the research type, their supervisors, when called upon to make a rating of them and to indicate chief points of weakness, did not find that their deficiencies were primarily lack of scholarship, training or technical ability, but rather temperamental and personality weaknesses. As illustration of what I have said, it will be of interest to this group to know that in 84 per cent of the cases, the chief deficiency was indicated to be a lack of coöperative ability, lack of tact, antagonistic attitude, unattractiveness of appearance, retiring disposition, unambitiousness or emotional instability. Sixteen per cent covers failure of ability along intellectual or engineering lines. This is high testimony to the results the schools have achieved in the field of the objectives they have set for themselves. Our urge is for the setting up of parallel objectives in the field of management.

Recommendations

We keep a record of the history of each individual who enters our Company. We have found that by far those who have stuck and have measured up are those who entered the organization immediately out of college through the apprenticeship. We know that in our organization there is a strong positive correlation between success and *continuity*. We feel that the advice frequently given seniors in some of our largest and reputable schools, "to drift about for the first five years to gain experience and settle down only after such experience has been gained" is decidedly ill-advised. Our experience is positively against this, and I want to give my best emphasis on this point in talking with you.

My second recommendation bears on a development of *group study and research*. Let these young men learn to work together, to give and to take—let them contribute as individuals to common projects the results of which take on significance only as the several parts are integrated. I know that this is blasphemy to some, and I know, too, that educational measurement under such a program becomes a far more difficult problem for the faculty, but it looks toward strengthening pronounced weaknesses and toward all-around development. It paves the way for what men must do in a successful modern industrial and engineering life.

The third recommendation, and the last I will offer, bears again in the same direction—toward *developing attitudes*, not by the addition of new courses on "Personality Building" or "Getting a Job," but through a more effective and genuine contact between you, the leading men of your faculty, and your students. Let this

objective come into every classroom and laboratory. I wonder if some of you who come from the largest and most highly organized of our great educational institutions realize what a handicap the very vastness of the institution is, with its buildings, its laboratories, its departments and its corps of instructors, each capable in his own technique, but not the type your graduates must be. I have visited most of the educational institutions of the country, over a period of fifteen years, and I have seen faculties at work. There are two types. There are those teachers who do not need to reach for the grade cards in discussing the qualifications of their students, who know the individual problems with which each has been confronted, and the way each has worked out his own salvation or failed to do so. There are those who have taken mental motion pictures of the growth of their men through the four years or longer period. There is fire in the eyes of these teachers and joy in their hearts, as they talk to you about their product. Then there are the others. Those who have only a few casual snapshots—mostly taken at random and indifferently developed.

A short time ago, I talked with the Dean of one of our leading schools, a graduate of one of our most important institutions, a man of practical engineering experience, as well as being an engineering dean of insight and wisdom. We were talking about this invitation you have extended to me to be here today, and this subject you have assigned. In his mind was the sense of the need for more vitality and real stimulation in our engineering schools. He related that he had graduated with a good record in Mining Engineering, had accepted a position with a mining company, had been engaged during his early years on the routine of development work, but had kept abreast of engineering developments, and during even his first few years out of school had contributed a number of recognized papers in his field of Mining Engineering. Five years out, he said, the opportunity came to him to return on a visit to his Alma Mater. He did so with real anticipation, but as he walked through the halls he passed many of his former professors, and not one of them recognized him. Then he came by one of the really great leaders and teachers of that institution—the head of another department with whom he had had little personal contact as an under-graduate. The Professor recognized the young graduate, shook hands with him, and in a passing moment of conversation remarked that he was gratified to note the progress being made, that he had followed with interest his contributions to mining engineering. "His remarks left me dumbfounded," said the Dean, "but I know now that that was the greatest stimulant to renewed effort that I ever received from my Alma Mater."

PHILOSOPHY OF TEXTBOOK TREATMENT AND PRESENTATION OF ALTERNATING CURRENT MACHINERY *

By A. S. LANGSDORF

Washington University

In an article by Professor H. H. Higbie entitled "Some Educational Objectives in the Writing of Textbooks," published in the November (1934) issue of *The Wiley Bulletin*, there is an interesting and complete analysis of the principles which should govern the preparation of textbooks in general. Anyone who contemplates pleasing his enemies by writing such a book would do well to read and digest what Professor Higbie has so admirably expressed. The article is somewhat too long to be condensed adequately into a few words, but at the risk of doing it injustice the main points may be thus summarized:

A really good text should be inspiring and self-teaching, not merely a compendium of information; it must not be so wordy as to leave the student no time to think in the possibly limited time available for study, nor so concise as to leave him floundering without the aid of an interpreter, and it should at the same time leave the way open for a good teacher to amplify the treatment in class discussions. It must undertake to establish proper standards of scholarship by the observance and inculcation of orderly habits of thought, developing the subject in a logical step-by-step manner so clearly presented and illustrated by suitable examples that the student will learn how to test his own thought process and to determine when his own conclusions are correct. It is suggested that each important new idea in order of presentation be developed by a concise generalized treatment, followed by particularized illustrations intelligible to the less gifted or less experienced reader; and that the interest of the student be sustained by giving him a bird's-eye view of the field, linking it wherever possible to personal experience, and occasionally using sprightly and colorful phrases. No attempt should be made to make the subject seem easier than it really is, but at the same time opportunity should be left to the student to experience the thrill of personal satisfac-

* Presented at the Conference on Electrical Engineering, Atlanta meeting, S. P. E. E., June 24–27, 1935.

tion that follows successful mastery and application of what he has learned.

These specifications outline an ideal not often realized, but certainly worth aiming at. Good textbooks are just as rare as good lectures, perhaps for the same reasons. Some wag once defined the lecture system as a device for transferring information from the notebook of the professor to the notebook of the student without allowing it to pass through the mind of either. That is a criticism that cannot so easily be directed against a textbook system of instruction, though most of us would be obliged to admit that if the material of some books passed through the mind of the author there must have been something wrong with the strainer. The printed text has the great advantage of permanence, and of making its appeal through the eye instead of through the ear; and yet, though the great majority of people are visual minded, it is known from the results of silent reading tests (and from written examinations based upon textbook material) that an astonishingly large percentage of readers will absorb the most unbelievably fantastic perversions of the ideas presented—as any collection of college boners abundantly proves. But the value of a textbook must be gauged in terms of the benefits derived from it, not by the boneheads, but by the reasonably good and by the superior students.

The subject of this particular discussion, to quote Dean Rodman, is "the matter of the philosophy of the mode of treatment" of alternating current machinery, and the hope "that out of the discussions might arise a greater uniformity in regard to material and methods of presentation which perhaps could lead eventually to the production of a much more satisfactory text than is at present available." His words reflect what is undoubtedly a widespread dissatisfaction with present methods of teaching this particular subject—or perhaps it would be more precise to speak of the unsatisfactory results of the teaching. Some of this dissatisfaction may be due to the scarcity of high class texts; but I believe that the real source is the faulty method of approach embedded in the more or less standardized curriculum in electrical engineering. It may be objected that there is no such thing as a standardized course of study, and it is true, of course, that there is none in the sense of uniform and identical arrangement. But in general it is true that the subject of alternating current circuits is not effectively presented until about the middle of the junior year, and that consideration of alternating current machinery is delayed until nearly the beginning of the senior year. Quite frequently such basic ideas as are inherent in the theory of induction motors remain untouched until the final semester of the senior

year, when the final threads of instruction must be woven together in a precipitous rush. Some of the responsibility for this unfortunate state of affairs arises from imperfect articulation between the component parts of the curriculum. For example, the preparatory course in physics is commonly placed in the sophomore year, and physics courses everywhere follow the ancient tradition that this branch of natural philosophy must begin with mechanics and proceed thence through acoustics, heat, and optics, to electricity and magnetism. Without in the least desiring to criticize the labors of able colleagues in the field of physics, I think it may be said that most teachers of junior students in electrical engineering find it necessary to drill their classes all over again in such apparently simple, but commonly egregiously misunderstood, matters as Ohm's and Kirchhoff's laws. In my opinion, the teaching of physics to engineering students is due—more correctly, is long over-due—for a thoroughgoing overhauling. Nearly all of the physics material dealing with statics and dynamics could be eliminated without any sacrifice, since it is much more thoroughly treated in courses in applied mechanics ordinarily begun in the latter half of the sophomore year. Such a condensation of subject matter would leave correspondingly more time for a more thorough treatment of the remaining topics, including the basic concepts of electricity and magnetism; and while the physics department would thus reach up to join hands with the electrical engineering department, the latter should reach down, by means of a properly articulated introductory course in the latter half of the sophomore year. This is being done in some institutions but more should follow suit. The chief purpose of such an introductory course should be two-fold: to drive home the fundamental ideas of electric and magnetic circuits and their interrelationship, illustrated by actual machines; and to emphasize the idea that the current in a circuit is much more commonly varying than steady. Looking back over my own experience as an undergraduate, if the personal element may be pardoned, I came up through the calm, serene domain of continuous currents to the troubled area of alternating quantities without realizing until long afterwards that I was being led from the particular to the general by teachers somewhat blind to the fact that they were following the trail of historical development. Others may not agree with me, but I believe there is still the notion in the minds of students that a great gulf divides alternating currents from the more familiar direct current, and that the transition involves a radical re-orientation of ideas. If the thought involved in the phrase "philosophy of treatment and presentation" can be applied to these considerations, I would say

that it should take the form of insisting early and often that direct currents represent only a special case of alternating or otherwise varying current, and that the general circuit laws should be applied from the very beginning to cases which include more than steady flow of continuous current. By making that beginning occur decidedly earlier than is now customary, there would be a gain not only in time but in clarity and comprehensiveness of prestation.

A good many years ago, when Professor Karapetoff wrote his book on The Magnetic Circuit, he expressed the opinion that the practice of dividing a book into separate chapters on transformers, alternators, convertors, induction motors, etc., tends to convey the impression that each of these is *sui generis;* each animal in its own cage, like a "zoo," separate and distinct from all the others, with its own peculiar characteristics and morphology. Perhaps I should apologize to Professor Karapetoff for dressing his idea in these words, which he did not use. But the philosophy underlying his view is one with which I have always been in hearty accord. The separation into chapters is not the important consideration, for that may be dictated by convenience to a considerable extent; the vital feature is to keep constantly in the foreground that every machine, no matter what the elements of which it is composed, is an aggregate of interlinked electric and magnetic circuits which must function in strict accordance with the basic laws of such circuits. These laws allow no exceptions, and the differences between machines arise solely from the grouping of the circuits. In all the voluminous literature on alternating current machines there is no clearer realization of this cardinal fact than in a classic paper by Atkinson, published about 1898 in the *Transactions of the British Institution of Civil Engineers;* long before there were any alternating current commutator type motors in use, that paper gave a clear analysis of the characteristics they must possess, and the conclusions were based upon reasoning so simply and clearly related to fundamental circuit relations that the original paper should be known to every student of the subject.

Another illustration of the desirability of tracing effects to fundamental laws is to be found in the theory of synchronous motors. Many books, and most students, seem to believe that the effect of varying field excitation upon the magnitude and phase of the armature current can only be explained by using rather elaborate vector diagrams. Yet the thing is absurdly simple; for it is easy to see, as in any motor, that the counter e.m.f. must be substantially equal in magnitude to the impressed voltage (the difference being accounted for by the relatively small impedance drop)

and therefore substantially constant if the impressed voltage is constant. If the counter e.m.f. is substantially constant, the flux must likewise be nearly constant, since the speed must be constant in a synchronous machine. If the flux remains practically constant, any alterations of field excitation must be counterbalanced automatically by a correspondingly opposite change in armature excitation. And since, long before this stage is reached, it has been shown that a lagging armature current tends to magnetize a motor, while a leading current demagnetizes, it follows at once that increasing field excitation demands a leading armature current. Such a purely qualitative explanation must of course be supplemented by more precise quantitative analysis, but the qualitative explanation does not lack rigor and it is certainly convincingly complete.

To recapitulate the idea I have endeavored to express, it seems to me that a thorough presentation of alternating current machines should aim to develop the ability to analyze the physical structure of a machine into a correspondingly related system of electric and magnetic circuits, to apply to these circuits the known laws, and thereby to derive by analytical processes the ultimate relations between dependent and independent variables.

One phase of this subject deserves additional attention, namely, the extent to which considerations of design should be incorporated. Several writers have protested vigorously against the intrusion of any material of this sort in books which set out to present and explain fundamental operating characteristics. The argument runs to the effect that only an insignificant number of graduates will ever become designers, and that the great majority, who will either operate the machines or else sell them to those who do, should not be pestered with such extraneous considerations. It needs no argument to prove that a book which aims primarily to treat fundamental principles should not at the same time aim to be a manual of design. But it seems to me that certain elementary design considerations are so closely tied to fundamental principles that to ignore them is inexcusable because they do so completely round out the picture. There are fundamental laws which forbid, for example, that the current in an armature conductor may be as great as 10,000 amperes per square inch of cross-section, and that fact and the reasons for it should be known even to a student who expects to be a salesman; otherwise he is apt to become like the chap who told a customer that *his* firm put more hysteresis in its machines than any concern on the market. To my mind, design considerations are useful and should be noted whenever they supplement basic principles, and especially when they help a student

to understand *why* results may be expected rather than merely *how* they are obtained.

There is another point which is extremely important to anyone who wishes to write a satisfactory book in the field under discussion: How much longer must we be content with "introductions" to this and that, and "elements" of the other, without a genuine attempt at a bang-up treatise? A genuine treatise does not exist on this side of the water, possibly because of modesty, or lack of ambition, or the limitations of a four-year course, or the necessity of writing down to a price that will sell—or all of these combined. It is my opinion that the time has come when the standard of instruction must be raised to a new and higher level.

One other item before bringing this discussion to a close: Altogether too many engineering texts are sprinkled with problems that are inexcusably stupid. The practice of inserting a batch of problems so placed as to indicate by their position what portion of the text is relevant is not open to serious objection if the aim is plainly to give an opportunity to use a particular formula or equation; but when the problem is so ridiculously worded that the procedure involves nothing more than term by term substitution and a subsequent slide rule manipulation, the thing is farcical. Just a little of that procedure is enough; it should be supplemented by numerous problems so worded as to simulate conditions under which problems are met in the real world, and these rarely carry any clue as to which formula is the right one to use. Problems of this type are not easy to evolve, but they are the necessary whetstones upon which the student should sharpen his wits.

APPLICATIONS OF MATHEMATICS TO ELECTRICAL ENGINEERING*

By W. J. SEELEY

Professor of Electrical Engineering, Duke University

My remarks on this subject will be confined to the work of the undergraduate student in electrical engineering; for it is with the undergraduate that the foundation of the field is laid, and with this in mind I should like to discuss with you one of the most important aspects of this foundation: mathematics and its application to the subject of electrical engineering.

It is almost axiomatic to say that "progress in electrical engineering is a function of mathematical proficiency." The men who stand at the head of their classes are almost invariably good mathematicians. The poor students, those deficient in mathematical proficiency, try to hide their deficiency by saying that they are practical, in contradistinction to theoretical; but in this case I am inclined somewhat to the opinion of Lord Beaconsfield who said that a practical man was one who practices the errors of his forefathers. Electrical engineering is a field in which good practice is built upon sound theory. The instructor is vitally interested in a most thorough presentation of such theory, and his theory is simply permeated with mathematics. Consequently, good mathematics is prerequisite to good electrical engineering, and the good mathematician makes a good engineer.

In a little book which he calls "An Introduction to Mathematics," A. N. Whitehead gives as the first sentence: "The study of mathematics is apt to commence in disappointment." I should like to add that it often continues and ends in disappointment, especially for engineers. This, I am afraid, is somewhat the fault of the mathematics instructor. He regards the mathematics of the engineer as a sort of prostitution of his conception of the subject—not really mathematics in the true sense of the word, but an offshoot which is more akin to computation than anything else. To the engineer mathematics is a means to an end, rather than the end itself. He calls it a "tool," much to the dismay and disgust of the mathematician. To degrade the mathematician's art to the classification of a tool is just too much for him, consequently, he is

* Presented at the Conference on Mathematics, Atlanta Meeting, S. P. E. E., June 24–27, 1935.

likely to be uninterested in teaching his art to a group which in time will relegate it to the classification to which the monkey wrench belongs.

If the teacher of mathematics could imbue the student with a modicum of the philosophy, ideals, and inspiration with which he is motivated in his research problems, the student would have a clearer conception and higher appreciation of mathematics as mathematics. He would be a more satisfactory student both in the mathematics classes and in the engineering classes. His mathematics teachers would be looked upon with inspirational appreciation rather than as taskmasters in drudgery; and the whole problem of teaching engineering would be on a much more satisfactory basis. But we never seem to be able to attain to our ideals. However, I should like to make a plea to the teachers of mathematics to attempt to inspire the student with an appreciation that the chief aim of mathematics is the construction of permanent and attractive highways of thought leading as directly as possible to important treasures of the intellect. That calls for instructors who are both cognizant of the use to which the mathematics are to be put, and who have a deep appreciation of and an interest in the aims and ideals of pure mathematics. That is a large order, difficult to fill, with the result that all too often the teaching of mathematics to engineers falls under Sir Josiah Stamp's dictum of "the inculcation of the incomprehensible in the minds of the ignorant by the incompetent."

This is not meant as a criticism of the teaching of mathematics, but more as a plea for the inspiration of the philosophy of mathematics in the minds of the engineering students. That will naturally have to come from the teacher of mathematics as the teacher of engineering is not capable of doing it. The teacher of engineering approaches mathematics from a utilitarian point of view, very often pulling theorems, processes, etc., from thin air and presenting them as being well known and not needing derivation and proof. He has neither time nor ability to prove them: he simply takes what he needs from the shelf and puts it to work just as he would take a tool from the tool box and use it at his convenience. The use of hyperbolic functions is an example of this procedure. Tables of integrals show that certain forms integrate into hyperbolic functions, and he makes use of the functions explaining that they stand for an infinite series similar to sine, cosine, or exponential functions. In fact, he says that they represent sums or differences of exponential series, for which tables have been computed, and then he proceeds to use the functions and tables without further comment or explanation. The continuous and varied use of hyperbolic functions eventually gives the student a fair under-

standing of something underlying their derivation; but there are others about which he learns nothing more than their existence and need in special cases, such for instance as Bessel's functions, which appear in the skin effect problem and certain transmission line problems. It is next to marvelous to see how the student can use a table of Bessel's functions and plot curves of results without having the least idea of what these functions are!

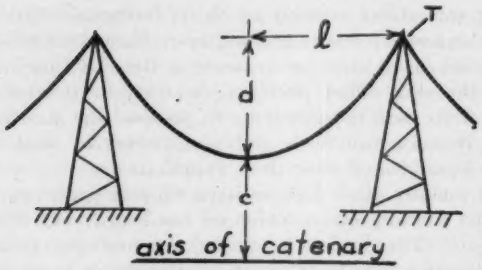
There are many other and perhaps simpler processes which the student must use and about which he has heard very little or perhaps nothing. These must be picked up and put to work with little investigation into their origin or derivation, trusting that the instructor has looked into them and found them rigorous and sound. Occasionally a student exercises a little healthy skepticism and gets his instructor into hot water. Usually he accepts everything in full faith, and then glories in the belief that he is becoming a marvelous mathematician. The engineering instructor unfortunately, and perhaps unwittingly, fosters such misbeliefs, but it is the result of the system rather than from a desire to belittle the importance of the underlying mathematics.

There are some very interesting mathematical transformations and processes that come up now and then in the teaching of electrical engineering which are not touched upon at all, or only very slightly, in the undergraduate mathematical courses. With good mathematical training, they are easily grasped; and with a little appreciation of the philosophy of mathematics they may be easily investigated to the satisfaction of the student. A rather interesting and innocent one arises in the study of the mechanics of suspended conductors of a transmission line. A consideration of the factors involved results in a catenary as the curve assumed by the suspended conductor. The design equations to be used for computation purposes become:

$$\frac{T}{wl} = \frac{c}{l}\cosh\frac{l}{c}, \tag{1}$$

$$d = c\left(\cosh\frac{l}{c} - 1\right), \tag{2}$$

In which T = tension at the point of support,
w = weight of conductor in pounds per foot,
l = one half the span length in feet,
c = distance from lowest point of curve to axis of catenary,
d = deflection in feet.



The quantities T, w, and l are known, it is desired to determine the deflection, d. The unknown constant, c, must therefore be eliminated from these equations before d can be found. That means that l/c must be found from equation (1). The equation looks very innocent, but students are suddenly dumfounded when they attempt to solve it by any method known to them. There are, of course, several methods, any one of which might be used for its solution, and an opportunity is immediately offered for a discussion of these methods of solving such equations. This type might be generalized into

$$A = \frac{1}{x} - f(x), \tag{3}$$

the function being simple hyperbolic, trigonometric, exponential, etc. Methods of solution immediately suggest themselves. Numerical solutions may be obtained by the cut and dry method from tables of the function: look up the function of x for any value of x, divide by x, and see if it equals A. Continue in this fashion until a close enough approximation is reached. Graphical methods also have been worked out and are available. However, if an analytical solution is desired the problem is a little more difficult. The student likes to see an equation in which x equals something. This gives an opportunity to outline a few of the possible methods. The Newton-Raphson method of approximation is one workable possibility. Another possibility is to express the function in terms of its series and then revert the series. This is an interesting and fascinating process and one worth outlining to the student. Both the above analytical solutions are laborious, however, and after several attempts the student usually goes to the cut and dry method.

Analysis of communication circuits very often results in numerical equations of degree higher than the third, the roots of which must be determined. Furthermore, some of these roots are

complex making the solution far from simple. The elementary theory of equations avoids all mention of complex roots except for second and third degree equations, and the well known Rule of Signs of Descartes does not always tell the truth, so the student is somewhat at sea as to a method of procedure. Any equation, of course, may be solved, but very often a tremendous amount of labor is required, so that unless definite methods are available the student is likely to give up the job as not being worth the effort. It is possible, however, to reduce somewhat the labor by a systematic approach. For example, take the rather formidable equation:

$$x^7 - 9x^6 + 36x^5 - 114x^4 + 429x^3 - 1761x^2 + 4394x - 4056 = 0. \quad (4)$$

By Descartes Rule of Signs this equation should have seven positive roots and zero negative roots, but an application of Horner's method of synthetic division and a few of the rules of the theory of equations yield the roots 2, 3, 4, $(2 \pm j3)$, $-(2 \pm j3)$, five positive and two negative. The solution is fairly straightforward and the work easy, especially since the roots are integral. But take an equation with fractional roots, such as:

$$x^7 - 5.245x^6 + 18.75x^5 + 220.4x^4 + 64.32x^3 - 108.6x^2 + 190.6x - 102.2 = 0. \quad (5)$$

The only feasible method of solving satisfactorily this equation is the Graffe * Root-Squaring method. This is a very pretty method, giving at once all roots, both real and complex, but it is somewhat laborious. The application of this method to equation (5) gives as the roots:

$$-3.79, -1.46, 0.545, (4.67 \pm j5.86), (0.257 \pm j0.745)$$

In order to obtain the correct signs for the roots, a knowledge of the theory of equations beyond that given in elementary texts is required. For instance, in equation (5), the first numerical coefficient

$$-5.245 = -[2(p + u + y + \cdots) + (a + b + c + \cdots)], \quad (6)$$

and the absolute term,

$$-102.2 = (-1)^n [(r_1^2 r_2^2 r_3^2 \cdots)(abc \cdots)], \quad (7)$$

where a, b, c, etc. = real roots,

p, u, y, etc. = real components of complex roots,

$$r_1^2 = p^2 + q^2,\ r_2^2 = u^2 + v^2,\ r_3^2 = y^2 + z^2.$$

* See "Calculus of Observations," by Whitaker and Robinson, or "Numerical Mathematical Analysis," by Scarborough.

Such equations as these are necessary to complete the work but, unless the student knows where to look for them or is enough interested to derive them, a good method is liable to fall down.

The operational calculus provides a rich source of material for mathematical discussion with the advanced undergraduate. In developing the fundamental ideas an excellent opportunity is opened up for reviewing the subject of linear differential equations, especially the partial fraction solution, showing how it evolves into an expansion theorem. The development of operational formulas, involving as it does a familiarity with expansion of functions into series and the recognition of series, and the check given by integral equations, requires a review of many of the fundamental principles of undergraduate mathematics. Even though nothing tangible is learned about the subject, the student at least has had an excellent review of nearly all his mathematics. If the material is properly presented it proves to be so fascinating that the student is stirred to the very depths of his mathematical soul and he takes a new interest in mathematics. However, as rich as this subject is in mathematics and as opportunistic as it is for teaching mathematics, the engineering instructor is primarily interested in it as a means for the analysis of electric circuits and he is anxious to get on with it as rapidly as possible so as to put it to work on his problems. Instead of pausing at resting places for profitable mathematical contemplation, he rushes on and all too often glosses over things that are somewhat obscure to him and more obscure to the student. He is more concerned with investigating circuit reactions than he is of mathematical reactions. I am sorry to have to confess that that that is somewhat of an indictment of the engineering teacher. Nevertheless, if the student possessed a proper appreciation of the art of mathematics and had caught an inspiration from his mathematics instructor, he would instinctively hesitate at the turns in the road and satisfy himself that the turns were justified. In spite of these criticisms, however, I should like to recommend heartily the subject of the operational calculus as a sort of dessert to the whole course of electrical engineering.

MECHANICAL ENGINEERING LABORATORY PRACTISE *

By L. M. K. BOELTER

Professor of Mechanical Engineering, University of California

The importance of laboratory instruction in the modern engineering curriculum is incontestable. It is well however to establish its position in the engineering educational program at the beginning of this paper.

Robert Duffus † defines science as "a process of experimentation and rationalization with the aid of which natural laws are formulated, tested, and utilized." He further states: "Scientific information has entered into every literate person's life to a greater or lesser extent. The scientific mode of thought has not." Herein lies a challenge to teachers of the sciences and engineering.

Quoting from Schrödinger: ‡ "The legitimate data of Physical Science are always and exclusively those arrived at by means of experiment. The first and indispensable condition that we demand of any process of experiment before it can be admitted into the regular procedure of physical research is that it will invariably reproduce the same results."

The basic laws of science, often termed fundamental principles, are therefore word, or algebraic, expressions of experimental results. These laws have been formulated with precision and the very conciseness of the statements often obscures the real significance. The basic laws cannot be applied to systems other than those upon which the experiments were conducted (models) and to similar systems (prototypes). Similarity of two systems implies that the ratio of the corresponding physical properties and dimensions of the two systems are finite, not equal to zero, and dimensionless. The behavior of two systems will be similar if the generalized exciting forces (or the energy fields) are identical in nature and in their variation with time. Criteria of similarity have been developed for various systems, for instance, Reynolds' number, Nusselt's number. One further restriction must be placed upon the extrapolation of experimental results (whether or not formulated algebraically) to similar systems—knowledge must be available fix-

* Presented at the Conference on Mechanical Engineering, Atlanta Meeting, S. P. E. E., June 24–27, 1935.

† "This Unscientific Age," December, 1934, *Harpers.*

‡ "Is Science a Fashion of the Times?" June, 1935, *Harpers.*

ing the accuracy with which the variables were measured in the original experiments.

All lecturers and experimenters have ample evidence of these restrictions. Consider for instance the difficulties which arise demonstrating the validity of Ohm's Law, $E = IR$, for a simple direct current circuit. Homogeneous materials must be used as resistances, the wire must be maintained at constant temperature throughout its volume, stray magnetic fields eliminated and instrument corrections applied. More to the point however is that if Ohm's Law is employed to predetermine the behavior of a simple circuit, its actual behavior will differ from the predetermined because the conditions mentioned will not be satisfied in the actual system.

Loose reasoning then permits the statement that the predetermined results differ because one is theoretical and the other practical. Actually, in the example cited, Ohm's Law will yield only the performance of the idealized system (*i.e.*, homogeneous material, isothermal, etc.). The basic laws are formulated for a given system (ideal) with a certain set of boundary and initial conditions. In case additional dependent energy fields exist in the prototype as contrasted with the original system (model and the ideal system), engineering judgment must be relied upon to weigh accurately their effect. The effects, if not negligible, must be determined by experiment in case data (formulated or otherwise) are not available for computation.

Mechanical engineering laboratory exercises of the past decade may be termed "macroscopic." For example, the average torque output of a reciprocating internal combustion engine was determined under steady state conditions with no thought of its periodic nature. Similarly the fuel consumption was measured for a period of time and the flow rate computed; the fact that the input was periodic was lost sight of.

The danger which lies in the application of the macroscopic view may be illustrated by a few examples:

(*a*) Calculation of a vapor film thermal conductance in a surface condenser and explaining the results without cognizance of the severe vapor storm existing within the condenser shell.

(*b*) Use of a cup anemometer to measure the velocity of the wind, which actually is highly variable (periodic in character).

(*c*) Extrapolation of heat transfer data (expressed in terms of Newton's Law of Cooling) of a system, involving dissipation by convection and radiation, to higher temperature differences.

(*d*) Explanation of engine cylinder condensation phenomena

without consideration of the periodic temperature difference existing between the vapor and the cylinder wall.

(*e*) Assuming the four terms in the force equation of a simple spring-mass system of a single degree of freedom.

$$\text{inertia} + \text{friction} + \text{restoration} = \text{excitation}$$

to be independent of each other.

The macroscopic view does not permit true idealization of the systems (*a*) to (*e*) cited above. The experimental results obtained cannot be explained correctly. Referring to (*b*) the behavior of a system in which the variables consist of unidirectional and steady state periodic components superposed cannot be explained by using the average value of the variables, but instead the r.m.s. value must be used.

It is therefore necessary to subject the systems to the "microscopic" point of view. The behavior of the variables must be revealed by adequate instrumentation. The variables to be measured are, in general, functions of mass, space, and/or time. For systems in equilibrium they may be independent of time or periodic functions thereof, or a system in the transient state may be under consideration. The variables may be scalar or vector quantities, unidimensional or *n*-dimensional. The analytical methods applicable to these experimental results must be used. Root mean square or instantaneous values will be employed rather than average values. More complex but satisfactory ideal systems will again become powerful tools.

The macroscopic point of view has not been outmoded. It will be utilized on pioneer experiments and results correlated therefrom may often be useful as convenient approximations. As the science of engineering progresses the macroscopic view will yield to the microscopic view which in turn becomes the macroscopic view with respect to a new mode of attack. For example, the gas law yields to the kinetic theory which in turn gives way to the electron theory.

In effect it may be stated that the methods of alternating and transient current phenomena are replacing those of direct current phenomena in mechanical engineering analyses. The modern developments of physics in kinetic theory and electron theory are of great value in dealing with the physical properties of the system. The infiltration of these methods and data must be reflected in the laboratory procedure.

The analysis of the behavior of a system is often expedited by considering analogous systems. If the force (or energy) relations and the boundary and initial conditions of two systems are similar, then the behavior of the two systems will be similar. For example,

electrical filters, acoustic filters and vibration eliminators are subject to the same form of treatment. And again is not Ohm's Law for the simple direct current circuit in the steady state a force equation with the inertia and restoring force terms omitted?

The educational experience of a student is pigeon-holed by courses, hours, units, etc. In each field the student learns a new vocabulary and what seem to him to be different methods. Much of this overlapping is unnecessary and often distinctly harmful because it leaves the student bewildered. The laboratory may lead the way toward a correlation of student educational experiences and sweep away the doubts and mysticism which generate the artificial bariers between the various fields of engineering knowledge in the mind of the student.

Consider again the system used to illustrate Ohm's Law. The behavior of the actual system can be predicted if the variation of the properties of the solid conductor due to non-homogeneity (chemistry and physics), the variation of resistance with temperature (heat transfer) and the eddy currents due to variable stray fields (electricity and magnetism) are considered. It may be seen that the problem is no longer one of a simple application of Ohm's Law, $E = IR$, but involves other fields of science. The properly organized laboratory sequence will offer the student the opportunity of analysis (regress from consequences to principles), of synthesis (progress from principles to consequences) and of the integration of his engineering experiences.

In the words of Ernst Mach * "scientific progress is a gradual accommodation of thought through a choice of what we find most useful and a rejection of the less productive." The laboratory experiences of the student should be so constituted as to include the same form of accommodation. Engineering laboratories must be organized to develop an experimental mode of attack and give free rein to the student's mental initiative. These laboratories cannot be justified if organized only to develop manual dexterity, to illustrate standard test procedure, or to verify previously learned facts.

In a paper presented before the Pacific Coast Aeronautics Meeting, A. S. M. E., June 9, 1932, Berkeley, the author traced the evolution of laboratory instruction in Mechanical Engineering at the University of California. In this paper a bare outline of the methods now used will be presented. Borrowing a leaf from the chemical engineer,† the fields of mechanical engineering have been di-

* Schrödinger, "Is Science a Fashion of the Times?" June, 1935, *Harpers.*

† "Study of Chemical Engineering by the Unit-Operation Method," Lewis and Haslam, Serial No. 24, M. I. T., July, 1922, and "The Place of Laboratory Work in a Chemical Engineering Curriculum," Badger, S. P. E. E.—S. S., 1931 Ann Arbor, not published.

vided into the following unit-operations (citing an incomplete set of subdivisions of each):

Thermodynamics
  Paths, cycles, energy conversion, combustion
Heat Transfer
  Conduction in solids
  Convection by gases and liquids
  Radiation in vacua and through gases, illumination
  Evaporation, condensation, humidification
Mechanics of Solids
  Statics, dynamics
  Vibration
  Transmission of power
Mechanics of Fluids
  Isothermal fluid flow
  Filtration
  Acoustics
  Plastic flow
Elasticity
  Forming, cutting, stability
Production Methods
  Tooling, time study, design (as an art)

Two further subdivisions are necessary:

Instrumentation and Mensuration
  Variable being measured (the exciting force)
  Characteristics of the exciting force
  Application of the exciting force to the mechanism
  Dynamical and thermal characteristics of the actuating mechanism
Properties of Materials
  Hardness, tensile strength, ductility, grain size, viscosity, specific heat, thermal conductivity, heat of combustion

Experiments illustrating the various subdivisions of the unit-operations are scheduled. A sufficient number of tests on complete machines involving a transformation of energy (or unit processes) are interspersed in order that the student will be forced to synthesize his unit-operations experiences. These machine tests also satisfy certain psychological needs of the mechanical engineering student.

The elementary sequence in fluid mechanics will be used to illustrate the schedule:

(*a*) Steady Flow of Fluids

The experiment is designed to illustrate the energy equation

and similarity of flow by the study of water through a glass tube. Correlation of experimental results obtained on tubes using air, oil, water and steam.

(*b*) Flow of air around an aerodynamic section
(*c*) Flow through orifices (water, oil, air) and nozzles (steam)
(*d*) Flow of oil in bearings
(*e*) Periodic flow of air in a manifold
(*f*) Principles of acoustics

The required engineering laboratory courses for the mechanical engineering student begin in the sophomore year for which two units credit are given for each of two semesters. The purpose of the engineering production laboratory [1] is to reduce orientation difficulties for the student upon entrance to upper division laboratory work. The laboratory procedure is outlined so as to emphasize the experimental method of attack. The schedule of experiments is designed to impart a basic knowledge of production operations and to observe the modifications of the properties of materials which result directly from these operations.

Some of the experiment groups are listed:

(*a*) Precision measurements of the dimensions of objects
(*b*) Orientation in machine processing
(*c*) Casting of metal including pattern making and molding
(*d*) Cutting of metals
(*e*) Forming of metals
(*f*) Welding of metals
(*g*) Heat treatment of metals

In the junior year the students enroll in an elementary strength of materials laboratory for one semester for which one unit credit is given. The course consists of physical tests of cement, steel, iron and wood. A two unit electrical engineering laboratory [2] for two semesters completes the junior laboratory requirements. The experiments are arranged to partially prepare the student for his senior work in the mechanical engineering laboratories. Briefly they consist of:

(*a*) Simple d.c. and a.c. circuits including three phase circuits
(*b*) Performance of direct current machines and predetermination
(*c*) Performance of transformers
(*d*) Performance of single phase and induction motors
(*e*) Performance of an alternator
(*f*) Motor starters and controllers
(*g*) Vacuum tube amplifier circuit, photocell and relays

[1] Under the direction of Prof. N. F. Ward.
[2] Under the direction of Prof. B. L. Robertson and Dr. T. A. Rogers.

The mechanical engineering laboratory work is not begun until the senior year. Credit value is set at four units each semester for each of two semesters. This work is not introduced earlier because it is felt that more than one major laboratory requirement each year is excessive. The introduction of mechanical engineering laboratory technique late in the student's college residence raises serious questions. These questions are being studied and a solution may be found by the development of a coöperative laboratory scheme for the junior year.

The fluid flow sequence, reference to which was made earlier in the paper, together with the other unit-operations named are scheduled for the senior year. The machine and unit process experiments are introduced from the following fields:

(*a*) Fuels and lubricants
(*b*) Heat power
(*c*) Automotive
(*d*) Aeronautics
(*e*) Hydraulic structures and machinery
(*f*) Photometry and illumination
(*g*) Acoustics

The gas engine experiment will be used to illustrate the preparation of the student for machine tests after having completed some of the exercises in unit-operations. The object of the test is to perform a heat balance on the engine. The unit-operations involved are periodic (intake and exhaust) and continuous (bearings) fluid flow, periodic combustion, thermodynamics (cycle and conversion of energy), periodic (to cylinder walls) and continuous heat transfer (to cooling water), dynamics (engine balancing, governor), and transmission of power (dynamometer). It may be seen that the analysis of the experimental results is much more readily accomplished by the student who is equipped with unit-operations laboratory experience.

Machine tests are grouped so that the student may readily correlate his laboratory experiences (example a: injector steam jet air pump, water jet pump, air jet pump; b: steam turbine and water reaction turbine; c: blower and centrifugal pump; d: complete steam power plant test including turbo-generator and engine load).

Throughout the senior year emphasis is placed upon original work by the student with the climax at the middle of the last semester. The student is then allowed to choose a project from a published list. The instructor in charge of the project develops a plan of attack and each party is allowed a choice of tasks within the plan adopted. A thesis is not required (optional for the more

capable students) for a Bachelor of Science degree in engineering for those students majoring in mechanical engineering. The organization of the work of the last semester presents most of the advantages of a thesis project with a greater net productivity.

The foregoing treatment has assumed engineering to be a science. It has been shown that the adequate solution of engineering problems demands a perspective which can only be gained through experimental (laboratory) experience. This experience must contain the elements of analysis, synthesis and integration. Special apparatus and technique must be developed to illustrate many of the unit-operations. These questions have been discussed in the author's previously quoted A. S. M. E. paper. The transition from exercises on ideal systems (the unit-operations may often be so constituted) to exercises on actual systems should be gradual and carefully planned. The exercises must be conducted from the microscopic point of view.

The organization used at the University of California in the senior year "cuts across" previously existing laboratory units, *i.e.*, the hydraulic laboratory and the mechanical laboratory. The older units are kept intact, each being under the supervision of a member of the staff who is responsible for its physical upkeep and development. From the point of view of instruction these older divisions do not exist. The laboratory schedule is based solely upon pedagogical requisites. Certain problems of supervision over the laboratory instruction and correlation with lecture courses must be continuously studied and solved.

Engineering as an art is not overlooked in the laboratory instruction. Observation of the general behavior of systems without recourse to numerical data is stressed. The instructor, by example and instruction, must direct the development of the student's engineering judgment.

NEW MEMBERS

BAUER, EDWARD E., Assistant Professor of Civil Engineering, University of Illinois, Urbana, Ill. M. L. Enger, W. C. Huntington.

CHURCHILL, R. V., Assistant Professor of Mathematics, University of Michigan, Ann Arbor, Mich. F. L. Bishop, Nell McKenry.

COIE, JOHN S., Assistant Professor of English, Washington State College, Pullman, Wash. F. W. Welch, M. K. Snyder.

DAHLENE, OSCAR, Professor and Head, Department of Mechanics, University of Alabama, University, Ala. G. J. Davis, D. A. DuPlantier.

HIGGINS, GEORGE J., Associate Professor of Aeronautical Engineering, University of Detroit, Detroit, Mich. H. E. Mayrose, C. J. Freund.

HUTCHINS, ROLAND E., Associate Professor of Civil Engineering, Rose Polytechnic Institute, Terre Haute, Ind. R. L. McCormick, C. Wischmeyer.

ISAACS, CHARLES A., Professor and Head, Department of Mathematics, Washington State College, Pullman, Wash. F. W. Welch, M. K. Snyder.

MATZKE, ARTHUR E., Research Assistant in Civil Engineering, Columbia University, New York City. J. K. Finch, W. J. Krefeld.

OAKEY, JOHN A., Instructor in Civil Engineering, Columbia University, New York City. Bruce Johnston, J. K. Finch.

DERONDE, LOUIS A., Assistant Professor of Mathematics, New York University, New York City. S. K. Barrett, C. E. Gus.

SCHMITZ, RICHARD R., Associate Professor of Industrial Education, University of Alabama, University, Ala. J. M. Gallalee, G. J. Davis.

SCHULDT, LESTER L., Instructor in English, University of Idaho, Moscow, Ida. I. C. Crawford, R. H. Hull.

YOUNG, DANA, Assistant Professor of Engineering, Connecticut State College, Storrs, Conn. P. G. Laurson, Earl R. Moore.

207 New Members, 3–30–36.

THE MACHINE DESIGN CLEARING HOUSE

By FRANK L. EIDMANN, Chairman,
Columbia University

During the present academic year the Machine Design Clearing House has eighty members. This group of the Machine Design Division of the S. P. E. E. exchanges problems in machine design and considers matters pertaining to the teaching of the subject. Problems and discussions are sent to the Chairman who has them manifolded and mailed to those who contribute to the financial support of the Clearing House. It has been found possible to operate the activity on annual dues of 50 cents.

The bulletins of the present year are listed below:

November—

"Designing—A Many-sided Career," by George F. Nordenholt, Editor, *Product Engineering,* a reprint from the A. S. M. E. Student Branch Bulletin of November 1935. Also a bulletin of general notes concerning the Clearing House and the Machine Design Division of the S. P. E. E.

January—

16 Questions on the Selection of Engineering Materials, contributed by Professor Wm. Howard Clapp, California Institute of Technology.

"A Design Problem Encountered in Connection with a Wire Cable Machine," contributed by F. C. Spencer, Planning Engineer, Western Electric Co.

February—

82 Questions Concerning the Selection of Engineering Materials, contributed by Frank L. Eidmann, Columbia University.

March—

"An Advanced Course in Engineering," by A. R. Stevenson, Jr., and A. Howard, of the General Electric Co.

April—

A general bulletin with miscellaneous notes of interest, and program for the Machine Design Conference at Madison.

"Laboratory Investigations of Machine Vibrations and Stresses," by J. J. Ryan, University of Minnesota.

May—

"The Content of a Course in Machine Design," by Professor P. H. Hyland, University of Wisconsin.

"An Analysis of the Relation of the Helix Angle to the Efficiency of Worm Gearing," by Mr. T. Colbert, University of Wisconsin.

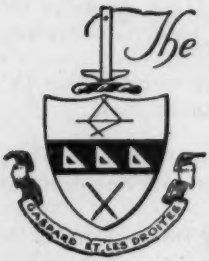
"Some Experiences in 30 Years of Teaching Machine Design," by J. V. Martenis, University of Minnesota.

June—

"The Place and Importance of Machine Design in the Engineering Curriculum," by P. K. Slaymaker, University of Nebraska.

"The Professional Setting of Machine Design," by C. A. Norman, Ohio State University.

"Should Machine Design be a Required Subject for All Engineering Students?" by D. G. Ryan, University of Illinois.



T-SQUARE PAGE

DEVOTED TO THE INTERESTS OF THE DIVISION OF ENGINEERING DRAWING

FREDERIC G. HIGBEE, EDITOR

The Annual Competition.—Chairman Carl L. Svensen has introduced a new and stimulating idea into the annual drawing competition by assigning a specific problem in three of the classes. Teachers of drawing owe it to themselves as well as to their students to enter. Those who win places and mentions will bring credit to their institution, and beyond doubt will be greatly stimulated to better work in engineering. Those who do not win will at least have the satisfaction of knowing that they were "on the team" chosen to compete with the best student draftsmen in the country. Regulations and assignments may be obtained from the chairman, Box 933, Lubbock, Texas. The regulations were also published in the JOURNAL, page 431–432.

Teaching Size Description.—Only in recent years have textbooks on engineering drawing adequately presented the subject of dimensioning. Even with this improvement, this subject remains the hardest part of engineering drawing to teach. There are so many places to put dimensions, so many factors affecting the kind of dimensions to give, so many points of view about essential sizes that a student is naturally confused. Without adequate knowledge of shop processes, with relatively little if any experience in selecting controlling factors in size information, a beginner needs considerable help. It is to be regretted that textbooks have not amplified the presentation of size description to include more examples of the correct and incorrect way to dimension.

Grading Drawings.—Theoretically a drawing should be graded very much as a drawing is checked in commercial drafting rooms. However grading may be done, several elements are important: the marking should be objective and constructive; the student's work should not be ruined in the process of noting errors; and every error should be noted. How can this be done? There are several systems: ideas on the subject would be of interest to all drawing teachers.

CIVIL ENGINEERING DIVISION

FRED L. PLUMMER, *Chairman* — H. C. BIRD, *Secretary*
FRANK KEREKES — K. C. REYNOLDS
L. E. GRINTER — H. E. BABBITT

THE COMMITTEE ON EDUCATIONAL POLICY AND TEACHING METHODS

BY H. S. ROGERS

Polytechnic Institute of Brooklyn

The Committee on Educational Policy and Teaching Methods was organized for the purpose of giving consideration to those broad objectives which are common to all engineering curricula and those specific objectives which are common to particular forms of courses. It is approaching its work and studies with the conviction that there are common objectives of a functional nature and common pedagogical procedures which may be most effective in various types of courses. To focus the thought and the discussion of the division upon these matters, it is preparing papers in which these characteristic objectives and methods will be outlined and presented.

The personnel of the Committee has been selected from among those men throughout the country who have given much thought and study to educational methods, and who have generalized, in their own manners, the pedagogical processes common to specific subject matter courses. The committee believes that progress in educational procedures can best be made by the efforts of engineering teachers themselves who may use the literature in education to guide them to a more fundamental understanding of principles and practices, but who will bridge the gap between abstract generalizations and their application in the engineering fields.

The Committee does not believe that the consideration of the pedagogical problems of engineering in terms of psychology and educational theory will materially change the pedagogy of engineering which has developed as a practical art. It does believe, however, that a consideration of the abstract and philosophical aspects of teaching will provide the common meeting-ground for teachers of different subjects, who now are separated by the divisions of natural science into its differentiated fields and by the differentiated practical fields of engineering applications.

To this end the Committee is preparing papers for the meeting in Madison in which it is the purpose to present the more fundamental aspects of this philosophy.

THE MADISON CONFERENCE

The program for the special conference to be held June 23–25 by the Civil Engineering Division is rapidly taking final form. The conference session to be held Tuesday afternoon, June 23, will be devoted to consideration of recent technical developments of interest to Civil Engineering Teachers. The work of the Forest Products Laboratories will be discussed and inspected on Wednesday afternoon June 24. The annual dinner of the Section will be held the same evening and this will be followed by entertainment. The final sessions to be held Thursday morning, June 25, will deal exclusively with the teaching of Civil Engineering Courses.

LETTER TO WRITERS OF TEXTBOOKS AND TECHNICAL PAPERS

Dear Brethren: A British reviewer more than forty years ago wrote of a textbook on Mechanics: "We have read the whole of the text with much interest. . . . The following errors we have noted. . . . The greater number of these errors are trifling, and will not give the private student much trouble; we have pointed them out because we know what a stumbling-block even slight mistakes are to such students. Their reverence for printed results is often wonderful. The utility of . . . 'High Trigonometry' is greatly hindered by the number of typographical blunders." (*Nature,* Vol. XLV, p. 101, December 3, 1891.)

A recent study of certain textbooks brings the above to mind. Their authors command profound respect yet the books are so marred by errors that the private student will at times have difficulty in following the text. The errors are mainly typographical. Many are trifling and can be easily detected, others are more serious.

In general, typographical errors follow certain lines. A plus sign is used where a minus sign is meant and vice versa. Equations are stated with an error in one of the terms. Four instances come to mind where the numeral 1 has been printed where the letter *l* was intended. This comes from the numeral and the letter having the same key on the typewriter. Equations should be handed to the printer in longhand, not typewritten. Errors like these handicap a book as an authority for reference. The decimal point is sometimes misplaced. Probably the most annoying errors are those where incorrect answers are given to examples. If an answer is wrong the private student is usually at sea. Moreover, an uncertainty is created in his mind as to the correctness of any part of the book he does not readily understand.

It is of interest to both author and publisher to have as few typographical errors as possible in a text. An outsider can not allocate blame in any particular instance unless he has a knowledge of the facts in that case. Some years ago the writer of an article excused grievous mistakes by writing that they were "typographical." The publisher printed his letter as he wrote it with a statement that the article had been sent to its author for approval and that it was published precisely as he returned it. An author leaving the work of final revision and proofreading to others has some-

times had dire results. The number of mistakes in the first edition of one book that ran through many editions was appalling. The explanation was that the correction of the manuscript and the proofreading had been assigned to the students of the senior class in the university of which the author was a professor. In another case the author left the manuscript with the instructors of his department and went to Europe. The instructors made sad work of it. A second edition allowed corrections to be made but this did not help purchasers of the first edition.

It is exceedingly difficult for a book to be brought out perfect in typography. The writer tried to do so in a book of his own but failed. One error called to his attention was quite annoying. On examination he found that the galley proof agreed with the manuscript. Both were correct. The page proof when sent for approval was examined rather carelessly and the change from the galley proof was not noticed. An author of his acquaintance found an error in the published book where the page proof was correct. The printer had dropped the form and reset the type without informing his superior.

The number of technical books and articles is on the increase. The safeguard against typographical errors is vigilance, vigilance and more vigilance on the part of both authors and publishers. Only by this method can errors be brought to a minimum.

ROBINS FLEMING,
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COLLEGE NOTES

Case School of Applied Science.—Dayton C. Miller, world renowned physicist and a distinguished member of the Case faculty for the past 46 years, will retire from active duty as head of the Physics department at the end of the present college year with the title of Professor Emeritus. He will serve, however, at the request of the trustees, as acting head of the department until June, 1937, the appointment of his successor being deferred until shortly before that time.

Doctor Miller was graduated from Baldwin-Wallace in 1887, at which time he received his Ph.B. degree. Three years later he received his M.A. degree at that college, after which he pursued post-graduate study at Princeton, there obtaining his Sc.D. in 1890. After a year as professor of natural sciences at Baldwin-Wallace he began his eventful career at Case where, from 1890–93 he taught as an instructor of mathematics and physics. For two years he served as an assistant professor of the physics department, but ever since 1895 he has been a full professor in that department.

Lewis Institute.—On September 1, 1935, Doctor George Noble Carman resigned after completing his fortieth successful year of service as Director of Lewis Institute. Doctor Carman will be remembered by the thousands of former Lewis students for his great interest in them as individuals and his unstinting personal attention given to their courses of study.

Upon Doctor Carman's resignation, Dugald C. Jackson, Jr., resigned from his position as Head of the department of Electrical Engineering at the University of Kansas and took over the duties of Director of Lewis Institute.

During the current year there have been a number of administrative and curriculum changes at the Institute. To supplement the present faculty advisory system, Professor C. L. Clarke was appointed Student Men's Adviser and Mrs. B. M. Gustafson, Student Women's Adviser. The curricula of civil, mechanical and electrical engineering have been revised in line with recent developments in various fields of engineering. Prominent alumni engineers have been obtained as consultants in the conduct of many courses.

With the resignation of Professor E. H. Lewis, Dean of Faculty and Head of the Department of English, Professor George L.

Tenney, Head of the Department of Foreign Languages, was made Acting Head of the Department of English. Upon the retirement of Professor W. P. Hawley, Associate Professor V. L. Sherman was appointed Acting Head of the Department of Mechanical Engineering. Assistant Professor F. R. Marks was appointed Acting Head of the Department of Mathematics to take the place of Professor H. E. Cobb who retired several years ago. Several engineering service courses have been grouped under the following heads: Associate Professor J. S. Kozacka in charge of courses in engineering drawing and allied courses; Assistant Professor F. H. Wade in charge of courses in applied mechanics; Assistant Professor L. J. Haga in charge of courses in metallurgy and metallography; Mr. Edwin Parre, in charge of shops and mechanic arts courses.

Two new instructors have been added to the Department of Physics. Benjamin Carpenter received his A.B. degree from Harvard in 1916 and his Ph.D. from Northwestern University in 1935. L. T. Anderson received his B.S. in E.E. from the University of Michigan in 1933, and his B.S. in mathematics and his M.S. in E.E. from the same institution in 1934.

R. K. Lidicker comes to Lewis Institute as Assistant in Civil Engineering. Mr. Lidicker received his B.S. degree from the University of Wisconsin in 1933.

The appointment of John M. Lessells, prominent consulting mechanical engineer, of Swarthmore, Pa., as associate professor of mechanical engineering at the **Massachusetts Institute of Technology,** has been announced. He will be occupied with teaching and research in the field of engineering materials.

Mr. Lessells was born in Scotland and served a five-year engineering apprenticeship there before graduation from Glasgow University. During the war he was employed on inspection of engine parts and materials for Rolls-Royce, Armstrongs and the British War Office. After the war, he joined the research staff of the Westinghouse Electric and Manufacturing Company of Pittsburgh, serving as manager of the applied mechanics division for eleven years. He later became engineering manager of the turbine and diesel department of Westinghouse at Philadelphia, a position from which he resigned recently to enter practice as consulting engineer to Westinghouse and others. In partnership with Professor G. B. Karelitz he has been identified with some of the mechanical details of the 200-inch telescope to be erected on Mount Palomar.

BOOK REVIEW

Commercial Alegebra, College Course. BOLLING H. CRENSHAW, THOMAS MARSHALL SIMPSON, AND JOSEPH M. PIRENIAN. New York, Prentice-Hall Inc., 1935. x, 174, viii pages. $2.00.

This book is designed "for the convenience of those desiring either (1) preparation for a course in compound interest and annuities (mathematics of finance) or (2) a course of more practical or utilitarian nature in the place of the traditional course in college algebra for groups whose field of concentration is neither mathematics nor a science requiring extended preparation in mathematics." It is the reviewer's opinion that the book admirably fulfills the avowed purpose of its authors.

It may be successfully pursued as a two hour, one semester, course by students who have had one year of high school algebra. The authors have taken great care to achieve simplicity, clearness and accuracy in their statements and it is no idle claim that the book to a great extent teaches itself. It seems, in fact, well adapted to the purpose of self instruction. Illustrative examples are freely used in which every step of the development is made clear. However, much opportunity remains for the student to test his grasp of the subject by working out the numerous exercises. In addition to the exercises following specific articles there is a miscellaneous set at the end of each chapter and a large set of general review problems at the end of the book. Answers to the odd-numbered exercises, excepting the miscellaneous and general review ones, are given. (Those for the even-numbered problems are supplied by the publisher on request of the instructor.)

A good chapter on elementary statistics has been included. Tables of six and seven place mantissas and an adequate index complete the book.

On the physical side the book is well bound and possesses an attractive format.

A. E. STANILAND

S. P. E. E. SUMMER SESSION IN ECONOMICS

ASSOCIATED WITH THE SIXTH ANNUAL ECONOMIC CONFERENCE FOR ENGINEERS AT THE STEVENS ENGINEERING CAMP, JOHNSONBURG, NEW JERSEY, JUNE 28–JULY 5, 1936

The Society for the Promotion of Engineering Education, at the invitation of Stevens Institute of Technology, will conduct at the Stevens Engineering Camp a summer session on the study of economics in engineering colleges and the place of economics in the engineering curriculum.

Teachers of economics and related subjects are especially invited to attend this session from June 28 (immediately following the annual meeting of the Society) to July 5. The day-by-day schedule of conferences and lectures is given below.

The sixth annual Economics Conference for Engineers will be in session at the Stevens Camp during this week. For further information concerning the program of that Conference in so far as it diverges from the S. P. E. E. program, address the President's Office, Stevens Institute of Technology.

Place of the Conference

The Conference is held at the Stevens Engineering Camp, at Johnsonburg, in the hill country of northern New Jersey—on the Delaware, Lackawanna and Western Railroad. Arrangements may be made for a camp car to meet trains at Johnsonburg or, if necessary, at Blairstown. There are excellent motor roads to camp from Philadelphia and New York (about 60 miles).

Accommodations

There are eighteen dormitory cabins scattered through the woods, a mess hall, at one end of which is the big fireplace around which evening conferences are held, and several instruction and service buildings. The buildings are wired for electric light. The camp has a modern sanitary system and water is supplied from an artesian well.

Recreation and Sports

Three athletic fields and the lake offer facilities for land and water sports. Blair Academy at Blairstown extends guest privileges for golf and tennis. Afternoons are free for recreation and sports.

Fees

One fee, $40, payable on arrival at camp, covers the enrollment fee, tuition, and all camp expenses, including camp and conference activities, bed and board, linen, blankets, towels, etc.

DAY-BY-DAY SCHEDULE—S. P. E. E. SUMMER SCHOOL *

	Sunday June 28	*Monday June 29*	*Tuesday June 30*	*Wednesday July 1*	*Thursday July 2*	*Friday July 3*	*Saturday July 4*	*Sunday July 5*
1st Morning Hour 8:45 A.M.	Registration and Cabin Assignments; Issue of Camp Equipment	**ECONOMIC THEORY (Seven Lectures) *** **Horace Taylor** (*Supervising*) *Assistant Professor of Economics and* **Raymond J. Saulnier,** *Instructor in Economics, Columbia University*						
		Fundamental Concepts of Value and Distribution Analysis	Interaction of Demand and Supply Forces in Determination of Market Price	Influence of Overhead Costs on Price; Problems of Joint and Composite Demand and Supply Conditions	Prices under Monopolistic Conditions; Influence of Collective Action on Prices	The Factors of Production and their Returns	Use of Money and Credit; their Relation to the Price System and Processes of Production	Economic Fluctuations—their Nature, Causes and Effects
2d Morning Hour 10:30 A.M.		**ASPECTS OF ENGINEERING ECONOMY**						
		A Possible Extension of the Principle of Increment Costs	Will an Investment Pay?	When should a Machine or Structure be Replaced?	Judgment Factors in Engineering Choice	New Aspects of Depreciation	Planning for Economic Performance	Current Sources of Information
		W. D. Ennis, *Professor, Stevens Institute of Technology*	**Laurence E. Frost,** *Consolidated Edison Co. of New York*	**Eugene L. Grant,** *Associate Professor, Stanford University*	**J. R. Shea** *Western Electric Company*	**Paul T. Norton, Jr.,** *Professor, Virginia Polytechnic Institute*	**Walter Rautenstrauch,** *Professor, Columbia University*	**W. D. Ennis**
Evening Lecture	Money	**ECONOMICS TODAY** The Engineer and the New Society	Labor Relations	Human Relations in Industry	Economics and Engineering	After All, It is an Engineering Course	After All, Engineers Have to be Human Beings	
8:15 P.M.	**Ray B. Westerfield,** *Professor of Political Economy, Yale University*	**Norman Thomas**	**Leo Wolman,** *Professor of Economics, Columbia University*	**T. North Whitehead,** *Asst. Prof. of Business, Harvard University*	**Harold G. Moulton,** *President, Brookings Institute*	**William McClellan,** *President Potomac Light & Power Co.*	**Harvey N. Davis,** *President, Stevens Institute of Technology*	

* It is suggested that each member of this course do certain reading in preparation for the work of the course, prior to the beginning of the session. The text which will be used is Alfred Marshall's "Principles of Economics," eighth edition, 1920. This book is published by the Macmillan Company, 60 Fifth Avenue, New York; price $6. It is desired that each member of the course read Books III, V and VI in this text. It is also suggested that before reading Marshall each student read a smaller work by H. D. Henderson, "Supply and Demand" (1922), the entire book. This latter volume is published by Harcourt Brace &

Enrollment and Cabin Reservations

To enroll address the President's Office, Stevens Institute of Technology, Hoboken, N. J. Members of the Conference are urged to enroll as early as possible.

S. P. E. E. Committee and Staff

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Stevens Institute of Technology
Eugene H. Fezandie, *Camp Executive*
Stevens Institute of Technology

SUMMER SCHOOL ON DRAWING AND DESCRIPTIVE GEOMETRY

The following is a summarized outline of the topics to be discussed at the Summer-School Conference of the Division of Drawing and Descriptive Geometry to be held at the University of Wisconsin, Madison, Wisconsin, June 19 and 22, just previous to the general Meeting of the Society.

Complete details and announcement of the contributors will be made in a special mimeographed outline to be mailed to the membership within a short time, as well as in the final program for the Meeting of the Society at Madison.

Friday, June 19, 1936

9:00 to 11:30

A. What Training in Graphics Does Industry Require of the Young Engineer?

1. Electrical Engineering.
2. Mechanical Engineering.
3. Civil Engineering.
4. Other Branches.

B. What Type of Training in Freshman Graphics Is Important to Progress in Remaining Period of Engineering Education?

1. Electrical Engineering.
2. Mechanical Engineering.

* It is suggested that each member of this course do certain reading in preparation for the work of the course, prior to the beginning of the session. The text which will be used is Alfred Marshall's "Principles of Economics," eighth edition, 1920. This book is published by the Macmillan Company, 60 Fifth Avenue, New York; price $6. It is desired that each member of the course read Book III, and VI in this text. It is also suggested that before reading Marshall read some such elementary work as Ely's "Outlines of Economics," and Seager's "Principles of Economics," the same book. This latter volume is published by Henry's Holt &

3. Civil Engineering.
4. Other Branches.

C. What Qualities and Special Training Are Important to Drawing Teachers?

1:30 to 3:30

D. How Best to Meet the Objectives of Skill and Speed in Drawing Courses.

E. Educational and Cultural Objectives of Courses in Drawing.

6:30 to 7:30

Dinner

Informal Get-together

SATURDAY, JUNE 20, 1936

9:30 to 11:30 A.M.

A. Should Instruction in Graphics Be Carried on Beyond the Freshman Year?

1. Under the direction of the Drawing Department?
2. As courses under the direction of specialized departments?

B. Present Day Needs in the Freshman Course in Drawing.

C. Present Day Needs in the Freshman Course in Descriptive Geometry.

1:30 to 3:30 P.M.

The Inter-relation of Teaching Problems in High School and College Curricula. To what extent are they dependent or independent of each other in the field of Drawing?

MONDAY, JUNE 22, 1936

9:30 to 11:30 A.M.

A. Do We Need to Teach the Graphic Language to Engineering Students?

B. Can Drawing Courses Be Made to Serve as Material for Orientation, and for Professional Application?

C. Testing Material—Its Purpose, Types and Uses (in a broad educational sense).

1:30 to 4:30 P.M.

METHODS

A. Class Room Teaching Methods and Special Devices.

B. Laboratory Methods and Special Devices.

C. Use of Special Equipment.

D. Films as an Instructional Medium and for Correlation Purposes.

G-E *Campus News*

CLEAN DIRT

SOAP and water will still be needed to clean Junior's face and hands, but if Junior's father is a florist he will welcome this clean dirt. Florists and specialty growers wage a never-ending battle against weeds, insects, and plant parasites which flourish in greenhouse soil. But reinforcements have arrived. Clean dirt may now be economically obtained by means of electric equipment developed by General Electric scientists.

Electric heating units, arranged in a wooden bin, heat a quantity of soil to a temperature of 160-180 F. Heating sterilizes the soil by a process which resembles the pasteurization of milk, and weed seeds, insects, and fungi which are dormant in the soil are killed during the sterilization process. In the resulting germless dirt, plants can attain a vigorous, uniform growth, free from the competition of weeds and the inroads of other plant enemies.

"AH, WATSON, AN INDUSTRIAL CRIME"

THE "corpus delicti"—a broken resistance wire; the suspect—a defect in the wire; the detective—a microchemist. With microscope and analytical apparatus of incredibly small dimensions this industrial superdetective finds tiny crystals of sulphate near the break. The trail leads to a nearby furnace giving off sulphurous fumes. Thus, the wire is cleared of suspicion of having been defective, and the criminal fumes are eliminated.

This analysis is typical of many industrial "micro-mysteries" that have been solved in the Research Laboratory of General Electric. A development from methods devised in the

fields of biology and medicine, microchemistry has become an indispensable servant to industry, with accomplishments as great as the quantities with which it deals are small.

With thimble-sized beakers, and test tubes as small as 1/50 of an inch in diameter, the microchemist analyzes quantities of material 17,000 times lighter than a drop of water. He has defined a new unit of mass, the gamma, one millionth of a gram. A streak of dirt, a smudge, a minute pit mark—all these can be taken into the laboratory with a reasonable assurance that the microchemist will be able to provide the answer to the problem.

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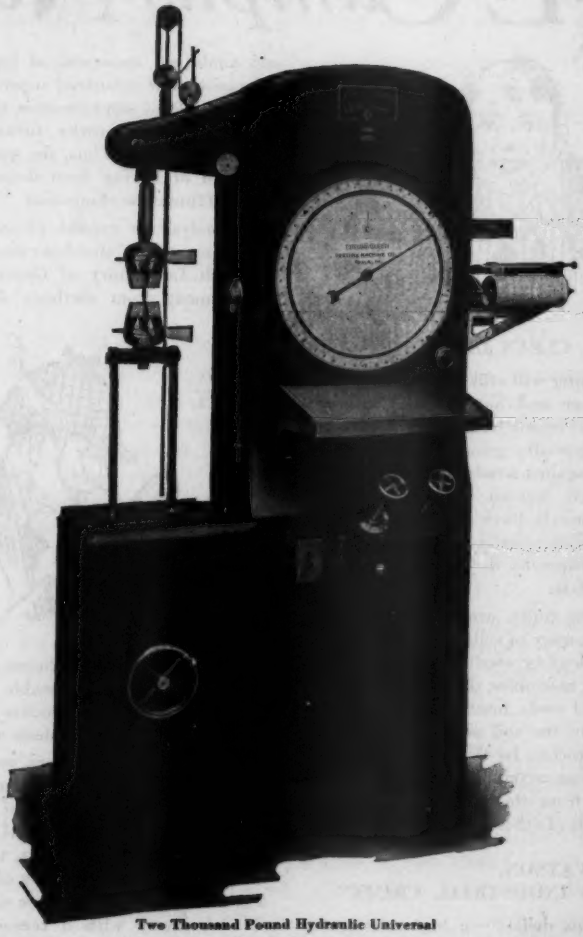
GENERAL ELECTRIC

PRECISION - - - -



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REINFORCED CONCRETE—Mechanics and Design

By ROBERT A. CAUGHEY, Professor of Structural Engineering, Iowa State College.

This book is distinctive in that it meets the requirements of the 1936 Report of the American Concrete Institute. It presents most clearly and forcefully the principles underlying the mechanics and design of reinforced concrete. The unusually great number of figures go far to clarify design problems. The liberal supply of problems, both with and without answers, is amply sufficient for the needs of every type of course and the individual preference of every instructor.

ELEMENTARY MECHANISM

By PHILIP K. SLAYMAKER, Professor of Machine Design, University of Nebraska.

This book emphasizes fundamental principles and their applications, developing its topics from the elementary concepts and arranging its material in logical order. The extent to which it achieves both clearness and brevity makes it possible to give the student a full working knowledge of mechanism within the limits of a three-hour course. As well as basic principles, it furnishes the facts and details needed in professional engineering.

DRAFTING FOR ENGINEERS—Second Edition

By CARL L. SVENSEN, M.E.

This greatly enlarged second edition retains the pedagogic features that were so highly regarded in the previous edition, including the approach to the subject of dimensioning which was originated by the author, and which is now so generally accepted. Many new chapters have been added, so that the book now covers pictorial drawing, electrical drafting, topographical drafting and many other subjects supplementary to engineering drafting.

DRAFTING PROBLEM LAYOUTS

By CARL L. SVENSEN and CHARLES H. SCHUMANN, JR.

Prepared to accompany the above text, "Drafting for Engineers," these sheets have been carefully designed to meet the practical needs of drafting instruction. More than 100 in number, they are the convenient 8½" x 11" size, printed on an excellent quality of drawing paper, and bound so that they are readily removable.

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